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CERTIFICATION REPORT

Preparation and Certification of Large-Sized Dried (LSD) Spike – IRMM-1027r

R. Jakopič, J. Bauwens, R. Buják, C. Hennessy,
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Abstract

Large-Sized Dried (LSD) spikes are used as a fundamental part of the fissile material control of irradiated nuclear fuel and have been provided on a regular basis to safeguards authorities and industry for more than 10 years. This report describes the preparation and certification of a new batch of LSD Spikes. IRMM-1027r is a dried nitrate material in cellulose acetate butyrate (CAB), certified for the mass of uranium and plutonium and isotope amount ratios per unit. The material was produced following ISO Guide 34:2009. The certified reference materials uranium metal EC NRM 101, enriched uranium metal NBL CRM 116-A and plutonium metal CETAMA MP2 were used as starting materials to prepare the mother solution. This solution was dispensed by means of an automated robot system into individual units and dried down. A solution of an organic substance, cellulose acetate butyrate (CAB), was dried on the spike material as a stabiliser to retain the dried material at the bottom of the vial. Between unit-homogeneity was quantified and stability during dispatch and storage were assessed in accordance with ISO Guide 35:2006. The certified values for the uranium and plutonium isotope amount ratios and for the mass of uranium per unit were obtained from the gravimetric preparation of the mother solution, taking into account the mass, purity and isotopic abundances of the starting materials, the mass of the mother solution, and the mass of an aliquot in each individual unit. Confirmatory measurements were performed by isotope dilution thermal ionisation mass spectrometry (ID-TIMS) and thermal ionisation mass spectrometry (TIMS). The certified values for the mass of plutonium per unit were established by ID-TIMS using IRMM-046b. Uncertainties of the certified values were estimated in compliance with the Guide to the Expression of Uncertainty in Measurement (GUM) and include uncertainties related to possible inhomogeneity and to characterisation. This spike CRM is applied as a calibrant to measure the uranium and plutonium amount content of dissolved spent nuclear fuel solutions using ID-TIMS. Each unit contains about 55 mg of uranium with a relative mass fraction $m(^{235}U)/m(U)$ of 18.6 % and 1.9 mg of plutonium with a relative mass fraction $m(^{239}Pu)/m(Pu)$ of 97.8 % as dried nitrates in CAB. The whole amount of sample per unit has to be used for analysis.

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Summary

Large-Sized Dried (LSD) spikes are used as a fundamental part of the fissile material control of irradiated nuclear fuel and have been provided on a regular basis to safeguards authorities and industry for more than 10 years. This report describes the preparation and certification of a new batch of LSD Spikes. IRMM-1027r is a dried nitrate material in cellulose acetate butyrate (CAB), certified for the mass of uranium and plutonium and isotope amount ratios per unit. The material was produced following ISO Guide 34:2009 [1].

The certified reference materials uranium metal EC NRM 101, enriched uranium metal NBL CRM 116-A and plutonium metal CETAMA MP2 were used as starting materials to prepare the mother solution. This solution was dispensed by means of an automated robot system into individual units and dried down. A solution of an organic substance, cellulose acetate butyrate (CAB), was dried on the spike material as a stabiliser to retain the dried material at the bottom of the vial.

Between unit-homogeneity was quantified and stability during dispatch and storage were assessed in accordance with ISO Guide 35:2006 [2].

The certified values for the uranium and plutonium isotope amount ratios and for the mass of uranium per unit were obtained from the gravimetric preparation of the mother solution, taking into account the mass, purity and isotopic abundances of the starting materials, the mass of the mother solution, and the mass of an aliquot in each individual unit. Confirmatory measurements were performed by isotope dilution thermal ionisation mass spectrometry (ID-TIMS) and thermal ionisation mass spectrometry (TIMS).

The certified values for the mass of plutonium per unit were established by ID-TIMS using IRMM-046b.

Uncertainties of the certified values were estimated in compliance with the Guide to the Expression of Uncertainty in Measurement (GUM) [3] and include uncertainties related to possible inhomogeneity and to characterisation.

This spike CRM is applied as a calibrant to measure the uranium and plutonium amount content of dissolved spent nuclear fuel solutions using ID-TIMS. Each unit contains about 55 mg of uranium with a relative mass fraction $m(^{235}U)/m(U)$ of 18.6 % and 1.9 mg of plutonium with a relative mass fraction $m(^{239}Pu)/m(Pu)$ of 97.8 % as dried nitrates in CAB. The whole amount of sample per unit has to be used for analysis.

The following values were assigned:

	Isotope amount ratios	
	Certified value [1)] [mol/mol]	Uncertainty [2)] [mol/mol]
$n(^{234}U)/n(^{238}U)$	0.0026629	0.0000022
$n(^{235}U)/n(^{238}U)$	0.23234	0.00004
$n(^{240}Pu)/n(^{239}Pu)$	0.022417	0.000006
$n(^{241}Pu)/n(^{239}Pu)$	0.0001551	0.0000020
$n(^{242}Pu)/n(^{239}Pu)$	0.0000757	0.0000008
The certified masses and the uncertainties of ^{235}U, ^{238}U and ^{239}Pu per unit are listed in Annex 1.		

[1)] The certified values are traceable to the values on the respective metal certificates (Annexes 2 - 6). The reference date for the plutonium and uranium isotope amount ratios is November 1, 2015.

[2)] The uncertainty is the expanded uncertainty with a coverage factor $k = 2$ corresponding to a level of confidence of about 95 % estimated in accordance with ISO/IEC Guide 98-3, Guide to the Expression of Uncertainty in Measurement (GUM:1995), ISO, 2008.

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Glossary

ANOVA	Analysis of variance
BIPM	Bureau International des Poids et Mesures (International Bureau of Weights and Measures)
c	amount of substance concentration
CAB	Cellulose acetate butyrate
CETAMA	Commission d'Etablissement des Methodes d'Analyse
CLSI	Clinical and Laboratory Standards Institute
CRM	Certified reference material
EC	European Commission
ESARDA	European Safeguards Research and Development Association
GUM	Guide to the Expression of Uncertainty in Measurement
IAEA	International Atomic Energy Agency
IDMS	Isotope dilution mass spectrometry
ID-TIMS	Isotope dilution thermal ionisation mass spectrometry
ISO	International Organization for Standardization
ITVs	International Target Values
JRC	Joint Research Centre of the European Commission
k	Coverage factor
LSD	Large-Sized Dried
m	mass
M	Molar mass
MS	Mass spectrometry
$MS_{between}$	Mean of squares between-unit from an ANOVA
MS_{within}	Mean of squares within-unit from an ANOVA
n	amount of substance
N	Mean number of replicates per unit
NBL	New Brunswick Laboratory
p.a.	pro analysis
rel	Index denoting relative figures (uncertainties etc.)
RM	Reference material
s	Standard deviation
s_{bb}	Between-unit standard deviation; an additional index "rel" is added when appropriate
SI	International System of Units

SDS	Safety data sheet
s_{wb}	Within-unit standard deviation
TIMS	Thermal Ionisation Mass Spectrometry
u	Standard uncertainty
U	Expanded uncertainty
u^*_{bb}	Standard uncertainty related to a maximum between-unit inhomogeneity that could be hidden by method repeatability; an additional index "rel" is added as appropriate
u_{bb}	Standard uncertainty related to a possible between-unit inhomogeneity; an additional index "rel" is added as appropriate
u_{char}	Standard uncertainty of the material characterisation; an additional index "rel" is added as appropriate
u_{CRM}	Combined standard uncertainty of the certified value; an additional index "rel" is added as appropriate
U_{CRM}	Expanded uncertainty of the certified value; an additional index "rel" is added as appropriate
u_{lts}	Standard uncertainty of the long-term stability; an additional index "rel" is added as appropriate
u_{sts}	Standard uncertainty of the short-term stability; an additional index "rel" is added as appropriate
$\bar{y}$	Arithmetic mean
α	Significance level
$\nu_{MSwithin}$	Degrees of freedom of MS_{within}

2 Introduction

2.1 Background

The International Target Values for Measurement Uncertainties in Safeguarding Nuclear Materials (ITVs) are uncertainties to be considered in judging the reliability of the measurement results of analytical techniques applied to industrial nuclear and fissile materials, which are subject to safeguards verification. ITVs should be achievable under the conditions normally encountered in typical industrial laboratories or during actual safeguards inspections. In 2010, the International Atomic Energy Agency (IAEA) together with the European Safeguards Research and Development Association (ESARDA), international standardisation organisations and regional safeguards authorities published a revised version of the ITVs [4]. The ITVs-2010 are intended to be used by nuclear plant operators and safeguards organisations as a reference of the quality of measurements necessary for nuclear material accountancy. The series of IRMM-1027 Large-Sized Dried (LSD) spikes are prepared by the JRC to meet the existing requirement for reliable isotope reference materials for the accountancy measurements of uranium and plutonium by IDMS in compliance with the ITVs-2010 in spent nuclear fuel. These spikes contain relatively large amounts of uranium and plutonium (55 mg U and 1.9 mg Pu), isotopically different to the uranium and plutonium in the test sample and are in dried nitrate form. About 1200 units of IRMM-1027 LSD spikes are prepared annually to fulfil the demands for fissile material control from European Safeguards Authorities and industry [5].

2.2 Choice of the material

The IRMM-1027r batch of LSD spikes was prepared from natural uranium (EC NRM 101), enriched uranium (NBL CRM 116-A) and plutonium (CETAMA MP2) certified reference metals. Each unit contains about 55 mg of uranium with a relative mass fraction $m(^{235}U)/m(U)$ of 18.6 % and 1.9 mg of plutonium with a relative mass fraction $m(^{239}Pu)/m(Pu)$ of 97.8 %. The relative mass fraction $m(^{235}U)/m(U)$ is below 20 %, so that for accountability purposes the uranium is classified as "low enriched". Individual units are certified for the mass of plutonium and uranium and for the isotope amount ratios. The uranium and plutonium amount content in a single IRMM-1027 LSD spike is such that no dilution of a typical sample of dissolved fuel is needed before measurement by IDMS. As the dried nitrates could flake off the vial surface over time or during transport, an organic polymer in the form of cellulose acetate butyrate (CAB) is added to retain the material at the bottom of the vial.

2.3 Design of the project

The individual units of IRMM-1027r LSD spikes were prepared by dispensing aliquots of the mother solution into vials and dried down. This solution was prepared gravimetrically by dissolving uranium and plutonium certified reference metals in hydrochloric and nitric acid. Hydrochloric acid was used for the first time in order to improve the dissolution of the plutonium metal. Finally, the dried nitrate was treated with CAB for preservation during storage and transport. The certified mass values of uranium and the uranium isotope amount ratios are based on the data given by the weighing certificates and the certificate of the starting materials. The certified mass values of plutonium are established by ID-TIMS. Confirmation measurements, along with the assessment of homogeneity and stability were made using IDMS analysis on randomly selected vials.

3 Participants

Project management and evaluation, processing, homogeneity study, stability study and characterisation have been performed at the European Commission, Joint Research Centre, Directorate – G.2 Standards for Nuclear Safety, Security and Safeguards in Geel, Belgium.

4 Material processing and process control

4.1 Origin and purity of the starting materials

CRMs of high purity uranium (EC NRM 101, Geel, Belgium and NBL CRM 116-A, Argonne, USA) and plutonium (CETAMA MP2, Marcoule, France) metals were used as starting materials for the preparation of the IRMM-1027r LSD spikes. The isotopic composition and the purity of the metals are given in Annexes 2 - 6.

4.2 Processing

Four units of plutonium MP2 metal for the preparation of the IRMM-1027r mother solution were weighed and transferred into a pre-cleaned 3 L borosilicate flask. The Pu metal was dissolved by addition of 45 mL of concentrated hydrochloric acid (*p.a.*, Merck, Darmstadt, Germany). About 1 L of nitric acid (c = 8 mol L^{-1}) was added and the solution left to homogenise for about 2 weeks. The respective units of enriched uranium metal (NBL CRM 116-A) and of natural uranium metal (EC NRM 101) were weighed and added into the above solution. Prior to weighing, the units of NBL CRM 116-A metal were etched with nitric acid (c = 1 mol L^{-1}) to remove surface oxidation products, and subsequently rinsed with deionised water and acetone (*p.a.*, Merck, Darmstadt, Germany) and dried down. A small amount of a black precipitate or residue was observed at the bottom of the flask after the addition of the uranium metals, despite additional dissolution step with hydrochloric acid. For this reason, the assignment of Pu mass fraction in the individual vials could not be based on the gravimetric preparation of the mother solution (e.g. mass of Pu metal, impurity, isotopic composition) but was established by isotope dilution thermal ionisation mass spectrometry (ID-TIMS). The final amounts of concentrated nitric acid and deionised water were added to adjust the concentration of the nitric acid solution (c = 5 mol L^{-1}). The solution was left to homogenise for a few days with occasional stirring by hand, and weighed to determine the final amount contents of the uranium and plutonium in the solution, taking into account the necessary corrections for air buoyancy effects.

Prior to dispensing the mother solution into individual vials four aliquots were analysed by ID-TIMS to verify the gravimetrically determined amount contents of plutonium and uranium and four aliquots by TIMS to verify the uranium and plutonium isotope amount ratios (see Section 3.3)

Dispensing and weighing of the solution into individual vials were performed by a validated automated system, which was installed at the JRC Geel in collaboration with Nucomat (Lokeren, Belgium) [6]. The major components of the system are a robot, two balances and a dispenser. The robot is software driven and designed to control all movements inside the glove box, such as identifying the vial with a barcode reader, dispensing and weighing of an aliquot of the solution (2.5 g) into the vials. The weighing component is equipped with an analytical balance (Sartorius TE124S, Göttingen, Germany) and a 5 kg balance (Sartorius TE6101, Göttingen, Germany) to monitor the mass of the mother solution during dispensing.

The whole solution (about 3 kg) was dispensed into 1151 units (identification numbers No.1-1152, vial No. 283 was discarded) over five consecutive working days.

The drying of the dispensed solution contained in the units was carried out on a hot plate. This temperature was increased to a maximum of 60 °C and the units were kept at this temperature for several days (typically 4-5 days continuous heating) to evaporate the solution completely. After the solution had dried, about 0.7 mL of CAB solution in acetone (10 g CAB/100g acetone, 35-39 g/100 g butyryl content, Acros, New Jersey, USA) was added. This solution was evaporated at room temperature and then heated to about 45 °C to dry completely. CAB was added to retain the dried material at the bottom of the vial so that it can resist physical shocks that might be encountered during transport and to avoid flaking of the material during long-term storage. This cellulose matrix dissolves readily in warm nitric acid solution and has no significant effect on the subsequent IDMS analysis. This has been demonstrated by measurements performed both on the vials (containing CAB) and on the mother solution (without CAB). Two separate glove boxes were used for drying and CAB application, allowing the preparation of up to 48 units per week. The vials were closed with a stopper and an aluminium cap, sealed in PVC package and labelled. The processing steps are shown in Figure 1.

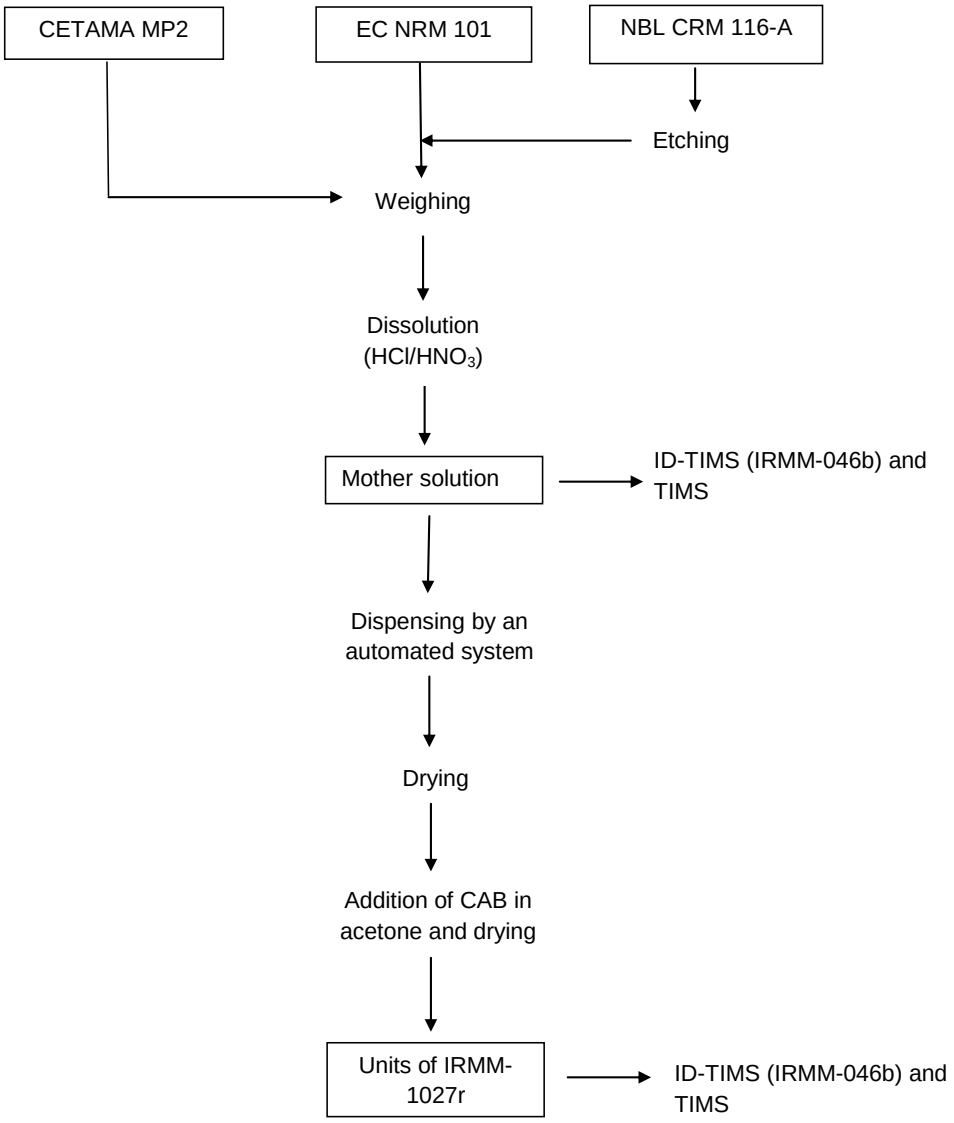

Fig. 1 Preparation of IRMM-1027r LSD spikes

4.3 Process control

This section describes the confirmation measurements performed on the mother solution prior to dispensing into individual vials.

Four aliquots (about 1.0 g each) were individually spiked with a mixed U/Pu spike CRM (IRMM-046b) for ID-TIMS analysis to confirm the amount contents of uranium and plutonium in the solution from gravimetric preparation. The IRMM-046b certificate can be found in Annex 7. Four unspiked aliquots were analysed to confirm the uranium and plutonium isotope amount ratios by thermal ionisation mass spectrometry (TIMS). The U/Pu separation of the spiked and unspiked samples was performed using anion-exchange columns (Bio-Rad AG1-X4, 100-200 mesh, Bio-Rad, Hercules, USA) as described in detail in [7].

The results of the confirmation measurements for ^{238}U and ^{235}U amount contents, the uranium and plutonium isotope amount ratios in the mother solution of IRMM-1027r agreed within the uncertainties with the values from the gravimetric preparation. However, a relative deviation of about -0.13 % from the gravimetric value was observed for the ^{239}Pu amount content. This deviation was due to the small amount of a fine precipitate or residue observed during the preparation of the mother solution (see 3.2). Consequently, the values obtained by the gravimetric preparation of the mother solution could not be used to assign the values for the mass of ^{239}Pu. Therefore the values for certified masses of ^{239}Pu were established by ID-TIMS (see 6.3). The results of the confirmation measurements for the mother solution of IRMM-1027r are shown in Annex 8 and Annex 9.

The units of IRMM-1027r LSD spike can be seen in Figure 2.

Fig. 2 Units of IRMM-1027r LSD spike

5 Homogeneity

A key requirement for any reference material is the equivalence between the various units. In this respect, it is relevant whether the variation between units is significant compared to the uncertainty of the certified value. In contrast to that it is not relevant if this variation between units is significant compared to the analytical variation. Consequently, ISO Guide 34 [1] requires RM producers to quantify the between unit variation. This aspect is covered in between-unit homogeneity studies. The homogeneity study was combined together with the measurements to confirm the gravimetric preparation of the IRMM-1027r LSD spikes.

5.1 Between-unit homogeneity

The between-unit homogeneity was evaluated to ensure that the certified values of the CRM are valid for all 1151 units of the material, within the stated uncertainty.

The number of selected units corresponds to approximately the cubic root of the total number of the produced units (1151). Ten units were selected to assess the homogeneity for the amount content using a random stratified sampling scheme covering the whole batch for the between-unit homogeneity test. The batch was divided into ten groups (with a similar number of units) and one unit was selected randomly from each group.

The homogeneity assessment of the uranium and plutonium isotope amount ratios was deemed not necessary.

The whole amount of sample per unit (equals minimum sample intake) was taken, chemically separated and the isotopic measurements were performed on a fraction of the purified sample. Each sample was measured in three replicates together with the isotopic standards to correct for instrumental mass fractionation. This enabled five independent samples to be measured on the same TIMS sample turret on the same day. Therefore, the measurements for all ten units of IRMM-1027r were performed under intermediate precision conditions rather than repeatability conditions. The respective fractions of the samples were measured in a randomised manner to be able to separate a potential analytical drift from a trend in the filling sequence. Some measurement results had to be excluded from the evaluation due to technical reasons, such as e.g. loss of sample prior to total evaporation measurement, high background from the filament due to unusually high filament temperatures or very low signal intensity. The results of the homogeneity study are shown in Annex 10.

Regression analyses were performed to evaluate potential trends in the analytical sequence as well as trends in the filling sequence. No trends in the filling sequence or the analytical sequence were visible.

Quantification of between-unit inhomogeneity was accomplished by analysis of variance (ANOVA), which can separate the between-unit variation (s_{bb}) from the within-unit variation (s_{wb}). The latter is equivalent to the method repeatability if the individual samples are representative for the whole unit.

Evaluation by ANOVA requires unit means that follow at least a unimodal distribution and results for each unit that follow unimodal distributions with approximately the same standard deviations. Distribution of the unit means was visually tested using histograms and normal probability plots. Minor deviations from unimodality of the individual values do not significantly affect the estimate of between-unit standard deviations. The results of all statistical evaluations are given in Table 1.

Table 1: Results of the statistical evaluation of the homogeneity studies of the amount content in IRMM-1027r

	Trends		Outliers		Distribution	
	Analytical sequence	Filling sequence	Individual results	Unit means	Individual results	Unit means
^{235}U	no	no	none	none	unimodal	unimodal
^{238}U	no	no	none	none	unimodal	unimodal
^{239}Pu	no	no	none	none	unimodal	unimodal

One has to bear in mind that $s_{bb,rel}$ and $s_{wb,rel}$ are estimates of the true standard deviations and therefore subject to random fluctuations. Therefore, the mean square between groups ($MS_{between}$) can be smaller than the mean squares within groups (MS_{within}), resulting in negative arguments under the square root used for the estimation of the between-unit variation, whereas the true variation cannot be lower than zero. In this case, u^*_{bb}, the

maximum inhomogeneity that could be hidden by method repeatability, was calculated as described by Linsinger *et al.* [8]. u^*_{bb} is comparable to the limit of detection of an analytical method, yielding the maximum inhomogeneity that might be undetected by the given study setup.

Method repeatability ($s_{wb,rel}$), between–unit standard deviation ($s_{bb,rel}$) and $u^*_{bb,rel}$ were calculated as:

$$s_{wb,rel} = \frac{\sqrt{MS_{within}}}{\bar{y}} \qquad \textbf{Equation 1}$$

$$s_{bb,rel} = \frac{\sqrt{\frac{MS_{between} - MS_{within}}{N}}}{\bar{y}} \qquad \textbf{Equation 2}$$

$$u^*_{bb,rel} = \frac{\sqrt{\frac{MS_{within}}{N}}\sqrt[4]{\frac{2}{v_{MSwithin}}}}{\bar{y}} \qquad \textbf{Equation 3}$$

MS_{within} mean square within a unit from an ANOVA

$MS_{between}$ mean squares between-unit from an ANOVA

$\bar{y}$ mean of all results of the homogeneity study

N mean number of replicates per unit

$v_{MSwithin}$ degrees of freedom of MS_{within}

The uncertainty contribution for homogeneity was determined under intermediate precision conditions because the isotopic measurements for all selected units of IRMM-1027r could not be carried out on the same day. Consequently, day-to-day effects can occur that could mask the between-unit variation. Therefore, the data were first checked using one way-ANOVA for any significant difference in between-day means. A significant day-to-day difference was observed for the ^{235}U and ^{238}U amount contents. For that reason, the data were first normalised by the respective day mean and the resulting data were evaluated using one way-ANOVA. The results of the evaluation of the between-unit variation are summarised in Table 2. The resulting values from the above equations were converted into relative uncertainties.

Table 2: Results of the homogeneity studies of the amount content in IRMM-1027r

	$s_{wb,rel}$ [1)] [%]	$s_{bb,rel}$ [1)] [%]	$u^*_{bb,rel}$ [1)] [%]
^{235}U content	0.0312	0.0082	0.0101
^{238}U content	0.0692	n.c.	0.0225
^{239}Pu content	0.0212	0.0121	0.0071

[1)] Rounding rules not applicable to the intermediate results

n.c. cannot be calculated, $MS_{between} < MS_{within}$

The homogeneity study showed no outlying unit means at a 99 % confidence level and no trends in the filling sequence at a 95% confidence level. Therefore, the between-unit standard deviation can be used as estimate of u_{bb}. As u^*_{bb} sets the limits of the study to detect inhomogeneity, the larger value of s_{bb} and u^*_{bb} is adopted as uncertainty contribution to account for potential inhomogeneity.

5.2 Within-unit homogeneity and minimum sample intake

The within-unit inhomogeneity does not influence the uncertainty of the certified value when the minimum sample intake is respected, but determines the minimum size of an aliquot that is representative for the whole unit. Sample sizes equal to or above the minimum sample intake guarantee the certified value within its stated uncertainty. The uranium and plutonium amount content in a single IRMM-1027 LSD spike is such that no dilution of a typical sample of dissolved fuel is needed. The only quantitative step needed at the reprocessing plant laboratory is to weigh as accurately as possible an aliquot of the dissolved fuel solution onto the spike and ensure complete mixing of spike and sample. The whole amount of sample per unit has to be used for analysis and thus equals the minimum sample intake. Quantification of within-unit inhomogeneity to determine the minimum sample intake for IRMM-1027r is therefore not necessary.

6 Stability

Stability testing is necessary to establish conditions for storage (long-term stability) as well as conditions for dispatch to the customers (short-term stability). The IRMM-1027r is a mixed U/Pu reference material, consisting of U and Pu radionuclides. Therefore, the certified isotope amount ratios and amount contents of this reference material are unstable by nature following the law of radioactive decay, depending on the respective half-lives [9,10].

Temperatures up to 60 °C could be reached for regular shipment of reference materials. Therefore, stability under these conditions had to be demonstrated. The shipment of nuclear material follows the legal requirements related to radioprotection measures for transport of radioactive materials. The packing of radioactive material is divided into two parts, the packing of the inner package and the packing of the container according to regulations and respective procedures [11]. Units of IRMM-1027r LSD spikes are sealed in plastic bags, put in a plastic Type A container for radioactive materials and are transported finally in large sealed containers. From the package material specification and the fact that the transport of radioactive material does not take longer than one week, the IRMM-1027r units packed as described above are never exposed to temperatures outside the range of 4 to 60 °C.

Taking into account that

1) Certified values of IRMM-1027r are valid for a specific reference date given on the certificate only;
2) The dried uranyl and plutonium nitrates are embedded in an organic substance providing a stable layer at the bottom of the vial to preserve the integrity during transport;
3) Preparation time of a batch of the IRMM-1027 series from dispensing of the mother solution until confirmation measurements on the completed LSD spikes in CAB takes about 6-10 months;
4) The packing of IRMM-1027r is such that the units are never exposed to temperatures outside the range of 4 to 60 °C;
5) Transport of IRMM-1027r does not exceed one week;

6) The JRC has provided IRMM-1027 series of LSD spikes for more than 10 years to customers

the short-term and long-term stability for the IRMM-1027 series are demonstrated in combination with the confirmation measurements and from experience in preparing the same kind of reference material over years, as described in detail in the certification report of IRMM-1027o by Jakopič et *al*. [7].

6.1 Short-term stability study

In the scope of the certification and preparation of the previous batch, IRMM-1027q, a thorough short-term stability study of the CAB was carried out [12]. The same CAB and chemical treatment were applied for the preparation of IRMM-1027r LSD spikes, therefore, the re-assessment of the short-term stability was deemed not necessary.

6.2 Long-term stability study

The IRMM-1027 batches of LSD spikes are produced and certified on an annual basis. The long-term stability for IRMM-1027r was demonstrated based on the verification results of IRMM-1027m over a period of four years after the certification in the context of the inter-calibration of JRC-IRMM spike CRMs [13,14,15]. As a further proof of the long-term stability of the IRMM-1027 series, selected units of IRMM-1027m were set aside and stored under room temperature conditions for already almost six years. Regular visual inspection showed that the CAB in these units stayed intact for five years. Some sign of deterioration (hair cracks and flaking) appeared in some of the vials after the storage time of more than five years. This has no consequence on the certified values since the certificate is valid for three years.

Furthermore, the long-term stability of the certified properties of IRMM-1027r is underpinned by measurement results from the previous batches as part of the post-certification monitoring, such as IRMM-1027o which has the same characteristics as IRMM-1027r. The results of the post-certification monitoring of IRMM-1027o are shown in Annex 11.

Furthermore, the JRC in Geel, Belgium (formerly known as the Institute for Reference Materials and Measurements, IRMM), the JRC in Karlsruhe, Germany (formerly known as the Institute for Transuranium Elements, ITU) and the IAEA are engaged in mutual verification measurements of mixed uranium/plutonium spike reference materials via an EC support task to the IAEA. In the frame of this support task verification measurements of randomly selected IRMM-1027 LSD spikes from different batches are performed up to two years after the certificate was issued, which is not only an external verification of the certified values but also a demonstration of the long-term stability of the IRMM-1027 series of LSD spikes.

6.3 Estimation of uncertainties

Due to the chosen approach of demonstrating the stability by combining confirmation and homogeneity assessment and taking into account points 1) – 6) as listed in section 5, no additional contribution from the stability study to the expanded uncertainty of the certified values of IRMM-1027r is taken into account.

Underpinned by internal confirmation, external verification and long-term monitoring of the IRMM-1027 series of LSD spikes in CAB, short- and long-term stability have been demonstrated. The IRMM-1027r certificate is valid for three years from the date of signature. The validity may be extended after further tests on the stability of the spike material are carried out. The material has to be transported according to the legal requirements related to radioprotection measures for the transport of radioactive materials. It is recommended to store the units of IRMM-1027 at + 18 °C ± 5 °C in an upright position.

After the certification campaign, this material will be subjected to the stability monitoring programme to control its stability. At least two units per year will be analysed in the nuclear laboratories of the JRC in Geel to confirm the certified values.

7 Characterisation

The material characterisation is the process of determining the property values of a reference material.

The material characterisation was based on gravimetric preparation for uranium and on isotope dilution mass spectrometry for plutonium. The IRMM-1027r series of LSD spikes was prepared by dispensing an aliquot (about 2.5 g) of the mother solution into individual units by an automated system and subsequent drying. The masses of dispensed aliquots per unit before drying are given in Annex 12. The mother solution was prepared by gravimetric mixing of uranium and plutonium metals (see Section 3.2 and Annex 13). Each individual unit of IRMM-1027r LSD spike is certified for the mass of ^{239}Pu, ^{235}U and ^{238}U and the $n(^{234}U)/n(^{238}U)$, $n(^{235}U)/n(^{238}U)$, $n(^{240}Pu)/n(^{239}Pu)$, $n(^{241}Pu)/n(^{239}Pu)$, and $n(^{242}Pu)/n(^{239}Pu)$ amount ratios.

7.1 Purity of the starting materials

The purity of the starting materials (metals) was taken from the corresponding certificates (Annexes 2 - 4). The purity of Pu MP2 metal was calculated for November 1, 2015 from the original purity of the CETAMA certificate (Annex 4).

7.2 Masses of ^{235}U and ^{238}U, U amount ratios and their uncertainties

The mass of ^{235}U and ^{238}U and the U isotope amount ratios in each individual unit of IRMM-1027r are calculated from the mass fraction of uranium in the mother solution, taking into account the mass of the metals and the solution, their purity and isotopic composition (e.g. isotope amount ratios), and the mass of an aliquot dispensed into each vial. In Table 3 the data supporting the calculation of the masses of ^{235}U and ^{238}U and Pu and U amount ratios per unit of IRMM-1027r are summarised.

Table 3: Gravimetric mixing to prepare the mother solution of IRMM-1027r

	MP2	EC NRM 101	NBL CRM116-A	Mother solution
Mass [1] [g]	2.21139	51.77549	12.40821	3005.42
Purity [2] [g/g]	0.9990	0.99985	0.99945	
Isotope amount ratios [3] [mol/mol]	$n(^{238}Pu)/n(^{239}Pu)$ 0.00003083 $n(^{240}Pu)/n(^{239}Pu)$ 0.0224324 $n(^{241}Pu)/n(^{239}Pu)$ 0.0002378 $n(^{242}Pu)/n(^{239}Pu)$ 0.00007570	$n(^{234}U)/n(^{238}U)$ 0.00005548 $n(^{235}U)/n(^{238}U)$ 0.0072593 $n(^{236}U)/n(^{238}U)$ 0.000000151	$n(^{233}U)/n(^{235}U)$ 0.0000003863 $n(^{234}U)/n(^{235}U)$ 0.0115836 $n(^{238}U)/n(^{235}U)$ 0.051277 $n(^{236}U)/n(^{235}U)$ 0.0094713	

[1] The masses of the metals are obtained from the weighing certificate, see Annex 14.

[2] The purity of the metals is obtained from the certificates, see Annexes 2 - 4.

[3] Amount ratios are obtained from the certificates, see Annexes 3 and 5 – 6.

The uncertainties on the certified mass (u_{char}) of ^{235}U and ^{238}U in the vial are composed of several contributions (Table 4), i.e. the uncertainty on the mass determination ($u_{char,1}$, $u_{char,2}$ and $u_{char,3}$), the uncertainty on the purity of the metals ($u_{char,4}$), and the uncertainty on the amount ratios ($u_{char,5}$). The complete and detailed calculations of the uranium mass fractions, amount ratios and their uncertainty budgets are given in Annex 13.

Table 4: Uncertainty budgets for the masses of ^{235}U and ^{238}U in vial No.80 of IRMM-1027r

	Standard uncertainty contribution					Combined relative uncertainty
	$u_{char,1}$ [1)] [g]	$u_{char,2}$ [2)] [g]	$u_{char,3}$ [3)] [g]	$u_{char,4}$ [4)] [g/g]	$u_{char,5}$ [5)] [mol/mol]	$u_{char,rel}$ [6)] [%]
^{235}U	0.000035	0.0125	0.0003	0.00006	0.000019	0.0134
^{238}U	0.000045	0.0125	0.0003	0.000025	0.0000035	0.0123

[1)] Standard uncertainty of the mass determination of the metals, see Annex 14.

[2)] Standard uncertainty of the mass determination of the mother solution, see Annex 14.

[3)] Standard uncertainty of the mass determination of an aliquot, see Annex 12.

[4)] Standard uncertainty of the purity of the metals, see Annexes 2 - 3.

[5)] Standard uncertainty of the isotope amount fraction (metals), see Annex 3 and Annex 13.

[6)] This final combined relative uncertainty is calculated using $\sum_{i=1}^{5}\sqrt{(u_{char,rel,i})^2}$. Note that rounding rules are not applicable to the intermediate results.

7.3 Masses of ^{239}Pu, Pu amount ratios and their uncertainties

The mass of ^{239}Pu in each individual unit of IRMM-1027r is calculated from the mass fraction of the plutonium established by ID-TIMS analysis using IRMM-046b as spike reference material on ten randomly selected vials, taking into account the mass of an aliquot of the mother solution (Annex 12), the mass of the spike in each blend (Annex 15), the amount content and isotopic composition of the IRMM-046b spike (Annex 7), and the isotope ratio measurements of the blend mixture (Annex 16). The uncertainties on the certified mass (u_{char}) of ^{239}Pu in the vial are composed of several contributions, i.e. the uncertainties on the mass determination of the sample and the spike ($u_{char,1}$ and $u_{char,2}$), the uncertainties on the amount content and isotope amount ratio of the spike ($u_{char,3}$ and $u_{char,4}$), the uncertainty on the isotope amount ratio measurements of the blend ($u_{char,5}$) and the uncertainty on the isotope amount ratio of the sample ($u_{char,6}$). In Table 5 the uncertainty contributions for the mass of ^{239}Pu in vial No.80 are summarised. The detailed calculations of the mass fractions, amount contents and their uncertainty budgets (e.g. propagation of various uncertainty contributions) in the selected units of IRMM-1027r are given in Annexes 17-19.

A general IDMS equation is shown below:

$$C_x = C_y \frac{m_y}{m_x} \frac{R_y - R_b}{R_b - R_x} \frac{\Sigma(R_i)_x}{\Sigma(R_i)_y} \qquad \textbf{Equation 4}$$

where C_y is the element amount content of the spike, m_x and m_y are the masses of sample and spike, respectively, R_x, R_y and R_b are the isotope amount ratios of the sample, the spike

and the blend, respectively, $\Sigma(R_i)_x$ and $\Sigma(R_i)_y$ are the sums of all isotope amount ratios in sample and in spike, respectively.

Table 5: Uncertainty budgets for the mass of ^{239}Pu in vial No. 80 of IRMM-1027r

	Standard uncertainty contribution						Combined relative uncertainty
	$u_{char,1}$ [1)] [g]	$u_{char,2}$ [2)] [g]	$u_{char,3}$ [3)] [µmol/g]	$u_{char,4}$ [4)] [mol/mol]	$u_{char,5}$ [5)] [mol/mol]	$u_{char,6}$ [6)] [mol/mol]	$u_{char,rel}$ [7)] [%]
^{239}Pu	0.0003	0.00006	0.00009	0.000008	0.0000295	0.00000039	0.0238

[1)] Standard uncertainty of the mass determination of an aliquot, see Annex 12.

[2)] Standard uncertainty of the mass determination of the spike (vial No 80), see Annex 15.

[3)] Standard uncertainty of the ^{242}Pu amount content in IRMM-046b, see Annex 7.

[4)] Standard uncertainty of the $n(^{239}Pu)/n(^{242}Pu)$ ratio in IRMM-046b, see Annex 7.

[5)] Standard uncertainty of the $n(^{242}Pu)/n(^{239}Pu)$ ratio in the blend (vial No. 80), see Annex 16.

[6)] Standard uncertainty of the $n(^{242}Pu)/n(^{239}Pu)$ ratio in the sample (MP2 certificate), see Annex 5.

[7)] The final combined relative uncertainty is calculated by propagating the uncertainty contributions as described in Annexes 17-19. Note that rounding rules are not applicable to the intermediate results.

7.4 Weighing and associated uncertainties

Masses of dispensed aliquots of the mother solution per unit used for the calculation of the certified values can be found in Annex 12. The dispensed masses were corrected for air buoyancy, taking into account the density of the air and the sample, the ambient humidity, temperature and pressure inside the glove box, and for the evaporation losses. Traceability to the SI is ensured by weighing a reference weight before and after dispensing a series of 96 units. The uncertainties on the dispensed mass are composed of several contributions, i.e. the uncertainty on the mass determination by an automated system, the uncertainty on the buoyancy correction, the uncertainty due to evaporation correction, and the uncertainty associated with the variability of the balance [6].

For the determination of the mass of the starting materials (metals) and the mother solution, substitution weighing was used. In the substitution weighing, the mass of a sample is determined through a series of mass determinations of an unknown (U) and a reference weight (S). The so called "SUUS" method was applied. The uncertainty contributions in substitution weighing of the metals are the uncertainties associated with the calibrated weights (certificate), air buoyancy correction and the variability of the balance used in "SUUS" method.

7.5 Confirmation measurements

Ten units of IRMM-1027r were randomly selected from the whole batch and analysed by ID-TIMS to confirm the uranium amount content obtained from the gravimetric preparation. To each of these vials, about 2.5 - 3 g of IRMM-046b mixed U/Pu spike in nitric acid (c = 5 mol L^{-1}) was weighed in and evaporated to dryness. Subsequently, the isotopic equilibrium, chemical separation and isotopic measurements on Triton TIMS were carried out [7]. The results of the confirmation measurements of the uranium amount content agreed well with the values from the gravimetrical preparation (Annex 20). The results of the confirmation measurements of the uranium and plutonium isotope amount ratios in the mother solution agreed well with the values from the gravimetrical preparation, except for the

$n(^{238}Pu)/n(^{239}Pu)$ amount ratios (Annex 9). This was due to an isobaric interference with ^{238}U coming from the incomplete removal of uranium in the plutonium fraction. This amount ratio was therefore not certified and is given only as additional material information.

The confirmation measurements of the uranium and plutonium isotope amount ratios in the selected units of IRMM-1027r LSD spikes were deemed not necessary. It was demonstrated in previous batches of LSD spikes that there was no significant difference observed between the measured isotope ratios in the mother solution and in the dried spikes [12,16]. The isotope fractionation during the evaporation of the nitrate solution (temperature below 60 °C) is negligible.

Due to the small precipitate or residue observed after the preparation of the mother solution, the ^{239}Pu values obtained by the gravimetric preparation could not be used to assign the certified masses. Therefore, the ID-TIMS using IRMM-046b spike was used as the sole analytical method to assign the certified values. No additional confirmation measurements could be performed within the time frame of the certification.

8 Value Assignment

Certified values are values that fulfil the highest standards of accuracy. Certified values for IRMM-1027r were assigned on the basis of gravimetric preparation and isotope dilution mass spectrometry as primary methods of measurement. Full uncertainty budgets in accordance with the 'Guide to the Expression of Uncertainty in Measurement' [4] were established.

8.1 Certified values and their uncertainties

The certified values (masses of ^{239}Pu, ^{235}U and ^{238}U and Pu and U isotope amount ratios) are based on the masses of the metals, their purity and isotopic composition, the mass of the mother solution and the mass of an aliquot dispensed into the vials. All weighings were carried out with a set of calibrated weights, directly traceable to the kg prototype at BIPM, Paris, with the necessary corrections for air buoyancy effects.

The assigned uncertainty consists of uncertainties related to characterisation, u_{char} (Section 7), potential between-unit inhomogeneity, u_{bb} (Section 5.1) and potential degradation during transport (u_{sts}) and long-term storage, u_{lts} (Section 6). As described in Section 5 the uncertainty related to degradation during transport and long-term storage was found to be negligible. These different contributions were combined to estimate the expanded, relative uncertainty of the certified value ($U_{CRM,\,rel}$) with a coverage factor k as:

$$U_{CRM,\,rel} = k \cdot \sqrt{u_{char,rel}^2 + u_{bb,rel}^2} \qquad \textbf{Equation 4}$$

- u_{char} was estimated as described in Section 6
- u_{bb} was estimated as described in Section 5.1.

Because of sufficient degrees of freedom of the different uncertainty contributions**,** a coverage factor k of 2 was applied to obtain the expanded uncertainties for all certified properties except for the mass of ^{239}Pu, for which the coverage factor of 2.3 was applied. The certified masses and their uncertainties for unit No. 80 are summarised in Table 6. The certified values of all 1151 units are given in Annex 1.

Table 6: Certified masses and their uncertainties in vial No.80 of IRMM-1027r as an example

Mass	Certified value [mg]	$u_{char, rel}$ [1)] [%]	$s_{bb, rel}$ or $u^*_{bb,rel}$ [1)] [%]	$U_{CRM, rel}$ [2)] [%]	U_{CRM} [2)] [mg]
^{239}Pu	1.7937	0.0238	0.0121	0.061	0.0011
^{235}U	9.925	0.0134	0.0101	0.034	0.003
^{238}U	43.262	0.0123	0.0225	0.051	0.022

[1)] Rounding rules not applicable to the intermediate results.

[2)] Expanded and rounded uncertainty (k = 2 for U and k = 2.3 for Pu).

The certified plutonium and uranium isotope amount ratios are summarised in Table 7.

Table 7: Certified isotope amount ratios and their uncertainties for IRMM-1027r LSD spikes (see as well Annex 13 and Annex 17 for the U and Pu amount ratios, respectively)

Isotope amount ratios	Certified value [1)] [mol/mol]	$u_{char, rel}$ [2)] [%]	$U_{CRM, rel}$ [%]	U_{CRM} [3)] [mol/mol]
$n(^{234}U)/n(^{238}U)$	0.0026629	0.0421	0.084	0.0000022
$n(^{235}U)/n(^{238}U)$	0.23234	0.00680	0.014	0.00004
$n(^{240}Pu)/n(^{239}Pu)$	0.022417	0.013385	0.027	0.000006
$n(^{241}Pu)/n(^{239}Pu)$	0.0001551	0.64475	1.29	0.0000020
$n(^{242}Pu)/n(^{239}Pu)$	0.0000757	0.5284	1.06	0.0000008

[1)] The reference date for the plutonium and uranium isotope amount ratios (Annex 17 and Annex 13, respectively) is November 1, 2015.

[2)] Rounding rules not applicable to the intermediate results.

[3)] Expanded (k = 2) and rounded uncertainty.

8.2 Additional material information

As additional information, the values for the plutonium and uranium amount contents, mass fractions and isotopic composition of the mother solution from gravimetric preparation and from ID-TIMS (see Annex 17-19 and Annex 13 for the Pu and U, respectively) are summarised in Table 8.

Table 8: Uranium and plutonium isotopic mass fraction, amount content, mass fraction and isotope amount ratios for the nitrate solution of IRMM-1027r

Additional Material Information

	Isotopic mass fraction	
	Value [1] [g/g]	Uncertainty [2] [g/g]
$m(^{234}U)/m(U)$ [3]	0.0021214	0.0000017
$m(^{235}U)/m(U)$ [3]	0.185881	0.000020
$m(^{236}U)/m(U)$ [3]	0.0017158	0.0000014
$m(^{238}U)/m(U)$ [3]	0.810282	0.000020
$m(^{238}Pu)/m(Pu)$ [3]	0.00002800	0.00000026
$m(^{239}Pu)/m(Pu)$ [3]	0.977734	0.000006
$m(^{240}Pu)/m(Pu)$ [3]	0.022010	0.000005
$m(^{241}Pu)/m(Pu)$ [3]	0.000153	0.000002
$m(^{242}Pu)/m(Pu)$ [3]	0.0000750	0.0000008
	Amount content	
	Value [1] [µmol/g solution]	Uncertainty [2] [µmol/g solution]
^{235}U	16.8858	0.0020
^{238}U	72.678	0.004
U	89.912	0.005
^{239}Pu	3.0006	0.0014
Pu	3.0687	0.0015
	Mass fraction	
	Value [1] [mg/g solution]	Uncertainty [2] [mg/g solution]
^{235}U	3.9690	0.0005
^{238}U	17.3010	0.0009
U	21.3518	0.0010
^{239}Pu	0.7173	0.0004
Pu	0.7337	0.0004
	Isotope amount ratios	
	Value [1] [mol/mol]	Uncertainty [2] [mol/mol]
$n(^{238}Pu)/n(^{239}Pu)$	0.00002876	0.00000027
$n(^{236}U)/n(^{238}U)$	0.0021355	0.0000017

[1] The reference date for the plutonium and uranium isotopic mass fraction, amount content, mass fractions and isotope amount ratios is November 1, 2015.

[2] Expanded uncertainty with a coverage factor $k = 2$, except for the plutonium amount content and plutonium mass fraction with a coverage factor $k = 2.3$. These values represent the expanded uncertainties from the characterisation of the mother solution (no homogeneity and stability assessment).

[3)] Isotopic mass fraction is expressed as $^{xxx}U/^{tot}U$ and $^{xxx}Pu/^{tot}Pu$.

9 Metrological traceability and commutability

9.1 Metrological traceability

Quantity value

The certified values are traceable to the values on the respective metal certificates (EC NRM 101, CETAMA MP2 and NBL CRM 116-A).

9.2 Commutability

Many measurement procedures include one or more steps, which are selecting specific analytes (or specific groups of analytes) from the sample for the subsequent steps of the whole measurement process. Often the complete identity of these 'intermediate analytes' is not fully known or taken into account. Therefore, it is difficult to mimic all the analytically relevant properties of real samples within a CRM. The degree of equivalence in the analytical behaviour of real samples and a CRM with respect to various measurement procedures (methods) is summarised in a concept called 'commutability of a reference material'. There are various definitions expressing this concept. For instance, the CLSI Guideline C-53A [17] recommends the use of the following definition for the term *commutability*:

> "The equivalence of the mathematical relationships among the results of different measurement procedures for an RM and for representative samples of the type intended to be measured."

The commutability of a CRM defines its fitness for use and, thus, is a crucial characteristic in case of the application of different measurement methods. When commutability of a CRM is not established in such cases, the results from routinely used methods cannot be legitimately compared with the certified value to determine whether a bias does not exist in calibration, nor can the CRM be used as a calibrant.

The IRMM-1027r is a dried nitrate in CAB certified for uranium and plutonium isotope amount ratios and masses of ^{235}U, ^{238}U and ^{239}Pu per unit. This CRM is tailor-made by the JRC for its intended use and serves as calibrant for uranium and plutonium IDMS measurements of samples from input solutions at reprocessing plants and is not intended to be used for other measurement methods.

10 Instructions for use

10.1 Safety information

The IRMM-1027r series contains radioactive material. The vials should be handled with great care and by experienced personnel in a laboratory suitably equipped for the safe handling of radioactive materials.

10.2 Storage conditions

The vials should be stored at + 18 °C ± 5 °C in an upright position.

Please note that the European Commission cannot be held responsible for changes that happen during storage of the material at the customer's premises, especially of opened vials.

10.3 Preparation and use of the material

The spike CRM has to be dissolved in the appropriate amount of acid (e.g. nitric acid with an amount of substance concentration c = 5 mol L^{-1}) or sample solution to ensure the isotopic equilibrium between the spike and the sample. Heating on a hotplate (avoid boiling) may be applied to assist the dissolution process.

10.4 Minimum sample intake

The whole amount of sample per unit has to be used for analysis.

10.5 Use of the certified value

This spike CRM is applied as a calibrant to measure the uranium and plutonium amount content in an unknown sample of dissolved nuclear fuel solution using isotope dilution mass spectrometry (IDMS). The amount content (C_x) of plutonium or uranium can be calculated using the following IDMS equation:

$$C_x = C_y \frac{m_y}{m_x} \frac{R_y - R_b}{R_b - R_x} \frac{\Sigma(R_i)_x}{\Sigma(R_i)_y} \quad , \qquad \textbf{Equation 6}$$

where C_y is the element amount content of the spike, m_x and m_y are the masses of sample and spike, respectively, R_x, R_y and R_b are the isotope amount ratios of the sample, the spike and the blend, respectively, $\Sigma(R_i)_x$ and $\Sigma(R_i)_y$ are the sums of all isotope amount ratios in sample and in spike, respectively.

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12 Annexes

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Annex 2: The certificate of EC NRM 101 uranium metal

Annex 3: The certificate of NBL CRM 116-A uranium metal

Annex 4: The certificate of CETAMA MP2 plutonium metal

Annex 5: The certificate of isotopic abundances of CETAMA MP2

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Annex 17: Combined uncertainty budget (turrets A and B) for the characterisation of plutonium in IRMM-1027r by ID-TIMS (normalised values to November 1, 2015)

Annex 18: Uncertainty budget for the characterisation of plutonium (turret A) of IRMM-1027r by ID-TIMS

Annex 19: Uncertainty budget for the characterisation of plutonium (turret B) of IRMM-1027r by ID-TIMS

Annex 20: Results of the confirmation measurements (10 units, 3 replicates) of ^{235}U and ^{238}U amount contents in the selected vials of IRMM-1027r

Annex 1: The certified masses of ^{235}U, ^{238}U and ^{239}Pu per unit (Vial No. 001 - 1152) of IRMM-1027r

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
001	43.567	0.022	9.994	0.003	1.8063	0.0011
002	43.559	0.022	9.992	0.003	1.8060	0.0011
003	43.264	0.022	9.925	0.003	1.7938	0.0011
004	43.427	0.022	9.962	0.003	1.8005	0.0011
005	43.361	0.022	9.947	0.003	1.7978	0.0011
006	43.359	0.022	9.947	0.003	1.7977	0.0011
007	43.439	0.022	9.965	0.003	1.8010	0.0011
008	43.373	0.022	9.950	0.003	1.7983	0.0011
009	43.420	0.022	9.961	0.003	1.8002	0.0011
010	43.384	0.022	9.952	0.003	1.7987	0.0011
011	43.292	0.022	9.931	0.003	1.7949	0.0011
012	43.432	0.022	9.963	0.003	1.8007	0.0011
013	43.392	0.022	9.954	0.003	1.7991	0.0011
014	43.370	0.022	9.949	0.003	1.7981	0.0011
015	43.427	0.022	9.962	0.003	1.8005	0.0011
016	43.368	0.022	9.949	0.003	1.7981	0.0011
017	43.354	0.022	9.946	0.003	1.7975	0.0011
018	43.441	0.022	9.965	0.003	1.8011	0.0011
019	43.372	0.022	9.950	0.003	1.7982	0.0011
020	43.413	0.022	9.959	0.003	1.7999	0.0011
021	43.353	0.022	9.945	0.003	1.7974	0.0011
022	43.288	0.022	9.931	0.003	1.7948	0.0011
023	43.401	0.022	9.956	0.003	1.7994	0.0011
024	43.373	0.022	9.950	0.003	1.7983	0.0011
025	43.379	0.022	9.951	0.003	1.7985	0.0011
026	43.394	0.022	9.955	0.003	1.7991	0.0011
027	43.399	0.022	9.956	0.003	1.7994	0.0011
028	43.404	0.022	9.957	0.003	1.7996	0.0011
029	43.333	0.022	9.941	0.003	1.7966	0.0011
030	43.332	0.022	9.940	0.003	1.7966	0.0011
031	43.392	0.022	9.954	0.003	1.7991	0.0011
032	43.373	0.022	9.950	0.003	1.7983	0.0011
033	43.321	0.022	9.938	0.003	1.7961	0.0011
034	43.304	0.022	9.934	0.003	1.7954	0.0011
035	43.346	0.022	9.944	0.003	1.7971	0.0011
036	43.408	0.022	9.958	0.003	1.7997	0.0011
037	43.361	0.022	9.947	0.003	1.7978	0.0011
038	43.363	0.022	9.948	0.003	1.7979	0.0011
039	43.398	0.022	9.956	0.003	1.7993	0.0011
040	43.330	0.022	9.940	0.003	1.7965	0.0011
041	43.339	0.022	9.942	0.003	1.7968	0.0011
042	43.340	0.022	9.942	0.003	1.7969	0.0011
043	43.385	0.022	9.953	0.003	1.7988	0.0011
044	43.406	0.022	9.958	0.003	1.7996	0.0011
045	43.328	0.022	9.940	0.003	1.7964	0.0011
046	43.321	0.022	9.938	0.003	1.7961	0.0011
047	43.339	0.022	9.942	0.003	1.7968	0.0011
048	43.262	0.022	9.925	0.003	1.7937	0.0011
049	43.297	0.022	9.932	0.003	1.7951	0.0011
050	43.410	0.022	9.958	0.003	1.7998	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
051	43.299	0.022	9.933	0.003	1.7952	0.0011
052	43.422	0.022	9.961	0.003	1.8003	0.0011
053	43.316	0.022	9.937	0.003	1.7959	0.0011
054	43.398	0.022	9.956	0.003	1.7993	0.0011
055	43.333	0.022	9.941	0.003	1.7966	0.0011
056	43.365	0.022	9.948	0.003	1.7979	0.0011
057	43.382	0.022	9.952	0.003	1.7986	0.0011
058	43.361	0.022	9.947	0.003	1.7978	0.0011
059	43.351	0.022	9.945	0.003	1.7974	0.0011
060	43.387	0.022	9.953	0.003	1.7989	0.0011
061	43.361	0.022	9.947	0.003	1.7978	0.0011
062	43.349	0.022	9.944	0.003	1.7973	0.0011
063	43.372	0.022	9.950	0.003	1.7982	0.0011
064	43.365	0.022	9.948	0.003	1.7979	0.0011
065	43.389	0.022	9.954	0.003	1.7989	0.0011
066	43.316	0.022	9.937	0.003	1.7959	0.0011
067	43.385	0.022	9.953	0.003	1.7988	0.0011
068	43.372	0.022	9.950	0.003	1.7982	0.0011
069	43.377	0.022	9.951	0.003	1.7984	0.0011
070	43.354	0.022	9.946	0.003	1.7975	0.0011
071	43.361	0.022	9.947	0.003	1.7978	0.0011
072	43.411	0.022	9.959	0.003	1.7999	0.0011
073	43.282	0.022	9.929	0.003	1.7945	0.0011
074	43.268	0.022	9.926	0.003	1.7939	0.0011
075	43.351	0.022	9.945	0.003	1.7974	0.0011
076	43.351	0.022	9.945	0.003	1.7974	0.0011
077	43.330	0.022	9.940	0.003	1.7965	0.0011
078	43.406	0.022	9.958	0.003	1.7996	0.0011
079	43.340	0.022	9.942	0.003	1.7969	0.0011
080	43.262	0.022	9.925	0.003	1.7937	0.0011
081	43.361	0.022	9.947	0.003	1.7978	0.0011
082	43.346	0.022	9.944	0.003	1.7971	0.0011
083	43.377	0.022	9.951	0.003	1.7984	0.0011
084	43.363	0.022	9.948	0.003	1.7979	0.0011
085	43.320	0.022	9.938	0.003	1.7961	0.0011
086	43.347	0.022	9.944	0.003	1.7972	0.0011
087	43.379	0.022	9.951	0.003	1.7985	0.0011
088	43.372	0.022	9.950	0.003	1.7982	0.0011
089	43.332	0.022	9.940	0.003	1.7966	0.0011
090	43.385	0.022	9.953	0.003	1.7988	0.0011
091	43.377	0.022	9.951	0.003	1.7984	0.0011
092	43.332	0.022	9.940	0.003	1.7966	0.0011
093	43.356	0.022	9.946	0.003	1.7976	0.0011
094	43.365	0.022	9.948	0.003	1.7979	0.0011
095	43.358	0.022	9.946	0.003	1.7976	0.0011
096	43.373	0.022	9.950	0.003	1.7983	0.0011
097	43.713	0.022	10.028	0.003	1.8124	0.0011
098	43.716	0.022	10.029	0.003	1.8125	0.0011
099	43.688	0.022	10.022	0.003	1.8113	0.0011
100	43.695	0.022	10.024	0.003	1.8116	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
101	43.810	0.022	10.050	0.003	1.8164	0.0011
102	43.635	0.022	10.010	0.003	1.8091	0.0011
103	43.654	0.022	10.014	0.003	1.8099	0.0011
104	43.721	0.022	10.030	0.003	1.8127	0.0011
105	43.732	0.022	10.032	0.003	1.8131	0.0011
106	43.668	0.022	10.017	0.003	1.8105	0.0011
107	43.642	0.022	10.012	0.003	1.8094	0.0011
108	43.751	0.022	10.037	0.003	1.8139	0.0011
109	43.699	0.022	10.025	0.003	1.8118	0.0011
110	43.728	0.022	10.031	0.003	1.8130	0.0011
111	43.657	0.022	10.015	0.003	1.8101	0.0011
112	43.690	0.022	10.023	0.003	1.8114	0.0011
113	43.732	0.022	10.032	0.003	1.8131	0.0011
114	43.671	0.022	10.018	0.003	1.8106	0.0011
115	43.770	0.022	10.041	0.003	1.8147	0.0011
116	43.659	0.022	10.015	0.003	1.8101	0.0011
117	43.721	0.022	10.030	0.003	1.8127	0.0011
118	43.680	0.022	10.020	0.003	1.8110	0.0011
119	43.685	0.022	10.021	0.003	1.8112	0.0011
120	43.726	0.022	10.031	0.003	1.8129	0.0011
121	43.692	0.022	10.023	0.003	1.8115	0.0011
122	43.737	0.022	10.033	0.003	1.8134	0.0011
123	43.725	0.022	10.031	0.003	1.8129	0.0011
124	43.642	0.022	10.012	0.003	1.8094	0.0011
125	43.744	0.022	10.035	0.003	1.8136	0.0011
126	43.732	0.022	10.032	0.003	1.8131	0.0011
127	43.683	0.022	10.021	0.003	1.8111	0.0011
128	43.706	0.022	10.026	0.003	1.8121	0.0011
129	43.720	0.022	10.029	0.003	1.8126	0.0011
130	43.702	0.022	10.025	0.003	1.8119	0.0011
131	43.692	0.022	10.023	0.003	1.8115	0.0011
132	43.749	0.022	10.036	0.003	1.8139	0.0011
133	43.683	0.022	10.021	0.003	1.8111	0.0011
134	43.766	0.022	10.040	0.003	1.8146	0.0011
135	43.515	0.022	9.983	0.003	1.8042	0.0011
136	43.661	0.022	10.016	0.003	1.8102	0.0011
137	43.707	0.022	10.027	0.003	1.8121	0.0011
138	43.725	0.022	10.031	0.003	1.8129	0.0011
139	43.668	0.022	10.017	0.003	1.8105	0.0011
140	43.680	0.022	10.020	0.003	1.8110	0.0011
141	43.688	0.022	10.022	0.003	1.8113	0.0011
142	43.735	0.022	10.033	0.003	1.8133	0.0011
143	43.688	0.022	10.022	0.003	1.8113	0.0011
144	43.702	0.022	10.025	0.003	1.8119	0.0011
145	43.699	0.022	10.025	0.003	1.8118	0.0011
146	43.681	0.022	10.021	0.003	1.8111	0.0011
147	43.697	0.022	10.024	0.003	1.8117	0.0011
148	43.763	0.022	10.039	0.003	1.8144	0.0011
149	43.687	0.022	10.022	0.003	1.8113	0.0011
150	43.697	0.022	10.024	0.003	1.8117	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
151	43.702	0.022	10.025	0.003	1.8119	0.0011
152	43.706	0.022	10.026	0.003	1.8121	0.0011
153	43.709	0.022	10.027	0.003	1.8122	0.0011
154	43.735	0.022	10.033	0.003	1.8133	0.0011
155	43.529	0.022	9.986	0.003	1.8047	0.0011
156	43.669	0.022	10.018	0.003	1.8106	0.0011
157	43.671	0.022	10.018	0.003	1.8106	0.0011
158	43.714	0.022	10.028	0.003	1.8124	0.0011
159	43.716	0.022	10.029	0.003	1.8125	0.0011
160	43.752	0.022	10.037	0.003	1.8140	0.0011
161	43.661	0.022	10.016	0.003	1.8102	0.0011
162	43.694	0.022	10.023	0.003	1.8116	0.0011
163	43.697	0.022	10.024	0.003	1.8117	0.0011
164	43.694	0.022	10.023	0.003	1.8116	0.0011
165	43.668	0.022	10.017	0.003	1.8105	0.0011
166	43.716	0.022	10.029	0.003	1.8125	0.0011
167	43.695	0.022	10.024	0.003	1.8116	0.0011
168	43.700	0.022	10.025	0.003	1.8118	0.0011
169	43.675	0.022	10.019	0.003	1.8108	0.0011
170	43.692	0.022	10.023	0.003	1.8115	0.0011
171	43.740	0.022	10.034	0.003	1.8135	0.0011
172	43.645	0.022	10.012	0.003	1.8096	0.0011
173	43.697	0.022	10.024	0.003	1.8117	0.0011
174	43.676	0.022	10.019	0.003	1.8108	0.0011
175	43.720	0.022	10.029	0.003	1.8126	0.0011
176	43.638	0.022	10.011	0.003	1.8093	0.0011
177	43.740	0.022	10.034	0.003	1.8135	0.0011
178	43.714	0.022	10.028	0.003	1.8124	0.0011
179	43.688	0.022	10.022	0.003	1.8113	0.0011
180	43.655	0.022	10.015	0.003	1.8100	0.0011
181	43.754	0.022	10.037	0.003	1.8141	0.0011
182	43.690	0.022	10.023	0.003	1.8114	0.0011
183	43.685	0.022	10.021	0.003	1.8112	0.0011
184	43.730	0.022	10.032	0.003	1.8131	0.0011
185	43.652	0.022	10.014	0.003	1.8098	0.0011
186	43.652	0.022	10.014	0.003	1.8098	0.0011
187	43.704	0.022	10.026	0.003	1.8120	0.0011
188	43.732	0.022	10.032	0.003	1.8131	0.0011
189	43.548	0.022	9.990	0.003	1.8055	0.0011
190	43.645	0.022	10.012	0.003	1.8096	0.0011
191	43.716	0.022	10.029	0.003	1.8125	0.0011
192	43.711	0.022	10.027	0.003	1.8123	0.0011
193	43.692	0.022	10.023	0.003	1.8115	0.0011
194	43.719	0.022	10.029	0.003	1.8126	0.0011
195	43.654	0.022	10.014	0.003	1.8099	0.0011
196	43.716	0.022	10.029	0.003	1.8125	0.0011
197	43.704	0.022	10.026	0.003	1.8120	0.0011
198	43.685	0.022	10.021	0.003	1.8112	0.0011
199	43.718	0.022	10.029	0.003	1.8126	0.0011
200	43.667	0.022	10.017	0.003	1.8105	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
201	43.683	0.022	10.021	0.003	1.8111	0.0011
202	43.626	0.022	10.008	0.003	1.8088	0.0011
203	43.735	0.022	10.033	0.003	1.8133	0.0011
204	43.688	0.022	10.022	0.003	1.8113	0.0011
205	43.723	0.022	10.030	0.003	1.8128	0.0011
206	43.676	0.022	10.019	0.003	1.8108	0.0011
207	43.678	0.022	10.020	0.003	1.8109	0.0011
208	43.673	0.022	10.019	0.003	1.8107	0.0011
209	43.747	0.022	10.036	0.003	1.8138	0.0011
210	43.648	0.022	10.013	0.003	1.8097	0.0011
211	43.622	0.022	10.007	0.003	1.8086	0.0011
212	43.569	0.022	9.995	0.003	1.8064	0.0011
213	43.659	0.022	10.015	0.003	1.8101	0.0011
214	44.412	0.023	10.188	0.003	1.8414	0.0011
215	44.469	0.023	10.201	0.003	1.8437	0.0011
216	43.531	0.022	9.986	0.003	1.8048	0.0011
217	43.629	0.022	10.009	0.003	1.8089	0.0011
218	43.474	0.022	9.973	0.003	1.8024	0.0011
219	44.486	0.023	10.205	0.003	1.8444	0.0011
220	44.388	0.023	10.183	0.003	1.8403	0.0011
221	44.440	0.023	10.195	0.003	1.8425	0.0011
222	44.429	0.023	10.192	0.003	1.8421	0.0011
223	43.562	0.022	9.993	0.003	1.8061	0.0011
224	44.424	0.023	10.191	0.003	1.8419	0.0011
225	44.372	0.023	10.179	0.003	1.8397	0.0011
226	44.412	0.023	10.188	0.003	1.8414	0.0011
227	44.409	0.023	10.187	0.003	1.8412	0.0011
228	43.515	0.022	9.982	0.003	1.8042	0.0011
229	43.584	0.022	9.998	0.003	1.8070	0.0011
230	44.483	0.023	10.205	0.003	1.8443	0.0011
231	43.546	0.022	9.990	0.003	1.8055	0.0011
232	44.431	0.023	10.193	0.003	1.8421	0.0011
233	44.433	0.023	10.193	0.003	1.8422	0.0011
234	44.421	0.023	10.190	0.003	1.8417	0.0011
235	43.562	0.022	9.993	0.003	1.8061	0.0011
236	43.553	0.022	9.991	0.003	1.8057	0.0011
237	43.616	0.022	10.006	0.003	1.8083	0.0011
238	43.510	0.022	9.981	0.003	1.8039	0.0011
239	44.360	0.023	10.176	0.003	1.8392	0.0011
240	43.661	0.022	10.016	0.003	1.8102	0.0011
241	43.539	0.022	9.988	0.003	1.8052	0.0011
242	43.520	0.022	9.984	0.003	1.8044	0.0011
243	43.596	0.022	10.001	0.003	1.8075	0.0011
244	44.419	0.023	10.190	0.003	1.8416	0.0011
245	43.551	0.022	9.991	0.003	1.8057	0.0011
246	44.419	0.023	10.190	0.003	1.8416	0.0011
247	43.581	0.022	9.998	0.003	1.8069	0.0011
248	43.588	0.022	9.999	0.003	1.8072	0.0011
249	44.362	0.023	10.177	0.003	1.8393	0.0011
250	44.407	0.023	10.187	0.003	1.8411	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
251	44.428	0.023	10.192	0.003	1.8420	0.0011
252	44.390	0.023	10.183	0.003	1.8404	0.0011
253	44.459	0.023	10.199	0.003	1.8433	0.0011
254	43.453	0.022	9.968	0.003	1.8016	0.0011
255	44.407	0.023	10.187	0.003	1.8411	0.0011
256	44.424	0.023	10.191	0.003	1.8419	0.0011
257	43.555	0.022	9.992	0.003	1.8058	0.0011
258	44.438	0.023	10.194	0.003	1.8424	0.0011
259	44.410	0.023	10.188	0.003	1.8413	0.0011
260	43.545	0.022	9.989	0.003	1.8054	0.0011
261	44.386	0.023	10.182	0.003	1.8403	0.0011
262	43.579	0.022	9.997	0.003	1.8068	0.0011
263	44.403	0.023	10.186	0.003	1.8410	0.0011
264	43.591	0.022	10.000	0.003	1.8073	0.0011
265	44.441	0.023	10.195	0.003	1.8426	0.0011
266	43.442	0.022	9.966	0.003	1.8011	0.0011
267	44.476	0.023	10.203	0.003	1.8440	0.0011
268	43.501	0.022	9.979	0.003	1.8036	0.0011
269	44.464	0.023	10.200	0.003	1.8435	0.0011
270	43.600	0.022	10.002	0.003	1.8077	0.0011
271	43.551	0.022	9.991	0.003	1.8057	0.0011
272	44.381	0.023	10.181	0.003	1.8401	0.0011
273	44.452	0.023	10.197	0.003	1.8430	0.0011
274	44.416	0.023	10.189	0.003	1.8415	0.0011
275	44.405	0.023	10.187	0.003	1.8411	0.0011
276	44.426	0.023	10.191	0.003	1.8419	0.0011
277	43.416	0.022	9.960	0.003	1.8001	0.0011
278	44.433	0.023	10.193	0.003	1.8422	0.0011
279	44.435	0.023	10.193	0.003	1.8423	0.0011
280	43.538	0.022	9.988	0.003	1.8051	0.0011
281	44.416	0.023	10.189	0.003	1.8415	0.0011
282	43.548	0.022	9.990	0.003	1.8055	0.0011
283	/	/	/	/	/	/
284	43.652	0.022	10.014	0.003	1.8098	0.0011
285	44.478	0.023	10.203	0.003	1.8441	0.0011
286	44.457	0.023	10.199	0.003	1.8432	0.0011
287	43.500	0.022	9.979	0.003	1.8035	0.0011
288	44.506	0.023	10.210	0.003	1.8452	0.0011
289	44.398	0.023	10.185	0.003	1.8408	0.0011
290	44.472	0.023	10.202	0.003	1.8438	0.0011
291	43.600	0.022	10.002	0.003	1.8077	0.0011
292	44.403	0.023	10.186	0.003	1.8410	0.0011
293	44.368	0.023	10.178	0.003	1.8395	0.0011
294	44.479	0.023	10.204	0.003	1.8441	0.0011
295	44.384	0.023	10.182	0.003	1.8402	0.0011
296	43.546	0.022	9.990	0.003	1.8054	0.0011
297	43.568	0.022	9.995	0.003	1.8064	0.0011
298	44.393	0.023	10.184	0.003	1.8405	0.0011
299	43.636	0.022	10.010	0.003	1.8092	0.0011
300	43.492	0.022	9.977	0.003	1.8032	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
301	44.422	0.023	10.191	0.003	1.8418	0.0011
302	44.432	0.023	10.193	0.003	1.8422	0.0011
303	43.619	0.022	10.006	0.003	1.8085	0.0011
304	44.401	0.023	10.186	0.003	1.8409	0.0011
305	44.408	0.023	10.187	0.003	1.8412	0.0011
306	44.441	0.023	10.195	0.003	1.8426	0.0011
307	43.553	0.022	9.991	0.003	1.8057	0.0011
308	44.415	0.023	10.189	0.003	1.8415	0.0011
309	43.508	0.022	9.981	0.003	1.8039	0.0011
310	44.445	0.023	10.196	0.003	1.8427	0.0011
311	43.539	0.022	9.988	0.003	1.8052	0.0011
312	44.415	0.023	10.189	0.003	1.8415	0.0011
313	44.377	0.023	10.180	0.003	1.8399	0.0011
314	44.467	0.023	10.201	0.003	1.8436	0.0011
315	44.268	0.023	10.155	0.003	1.8354	0.0011
316	44.448	0.023	10.196	0.003	1.8428	0.0011
317	44.360	0.023	10.176	0.003	1.8392	0.0011
318	43.532	0.022	9.986	0.003	1.8049	0.0011
319	43.501	0.022	9.979	0.003	1.8036	0.0011
320	43.523	0.022	9.984	0.003	1.8045	0.0011
321	44.318	0.023	10.167	0.003	1.8375	0.0011
322	44.391	0.023	10.183	0.003	1.8405	0.0011
323	44.299	0.023	10.162	0.003	1.8367	0.0011
324	44.391	0.023	10.183	0.003	1.8405	0.0011
325	43.411	0.022	9.959	0.003	1.7998	0.0011
326	44.434	0.023	10.193	0.003	1.8423	0.0011
327	43.587	0.022	9.999	0.003	1.8072	0.0011
328	44.374	0.023	10.179	0.003	1.8398	0.0011
329	44.470	0.023	10.202	0.003	1.8438	0.0011
330	44.356	0.023	10.175	0.003	1.8390	0.0011
331	44.419	0.023	10.190	0.003	1.8416	0.0011
332	44.429	0.023	10.192	0.003	1.8421	0.0011
333	43.539	0.022	9.988	0.003	1.8052	0.0011
334	44.393	0.023	10.184	0.003	1.8405	0.0011
335	44.427	0.023	10.192	0.003	1.8420	0.0011
336	44.417	0.023	10.189	0.003	1.8415	0.0011
337	44.320	0.023	10.167	0.003	1.8375	0.0011
338	44.316	0.023	10.166	0.003	1.8374	0.0011
339	43.362	0.022	9.947	0.003	1.7978	0.0011
340	44.273	0.023	10.156	0.003	1.8356	0.0011
341	43.549	0.022	9.990	0.003	1.8056	0.0011
342	44.289	0.023	10.160	0.003	1.8362	0.0011
343	44.460	0.023	10.199	0.003	1.8433	0.0011
344	44.218	0.023	10.144	0.003	1.8333	0.0011
345	44.431	0.023	10.193	0.003	1.8421	0.0011
346	43.537	0.022	9.988	0.003	1.8051	0.0011
347	44.412	0.023	10.188	0.003	1.8413	0.0011
348	43.589	0.022	9.999	0.003	1.8072	0.0011
349	44.363	0.023	10.177	0.003	1.8393	0.0011
350	44.429	0.023	10.192	0.003	1.8421	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
351	43.544	0.022	9.989	0.003	1.8054	0.0011
352	43.423	0.022	9.961	0.003	1.8003	0.0011
353	44.425	0.023	10.191	0.003	1.8419	0.0011
354	44.406	0.023	10.187	0.003	1.8411	0.0011
355	43.563	0.022	9.994	0.003	1.8062	0.0011
356	44.386	0.023	10.182	0.003	1.8403	0.0011
357	44.493	0.023	10.207	0.003	1.8447	0.0011
358	43.497	0.022	9.978	0.003	1.8034	0.0011
359	44.445	0.023	10.196	0.003	1.8427	0.0011
360	43.523	0.022	9.984	0.003	1.8045	0.0011
361	43.561	0.022	9.993	0.003	1.8061	0.0011
362	43.650	0.022	10.013	0.003	1.8097	0.0011
363	43.549	0.022	9.990	0.003	1.8056	0.0011
364	44.335	0.023	10.171	0.003	1.8382	0.0011
365	43.572	0.022	9.996	0.003	1.8065	0.0011
366	44.396	0.023	10.185	0.003	1.8407	0.0011
367	44.417	0.023	10.189	0.003	1.8415	0.0011
368	44.438	0.023	10.194	0.003	1.8424	0.0011
369	44.384	0.023	10.182	0.003	1.8402	0.0011
370	44.434	0.023	10.193	0.003	1.8423	0.0011
371	43.546	0.022	9.990	0.003	1.8054	0.0011
372	43.565	0.022	9.994	0.003	1.8062	0.0011
373	44.448	0.023	10.196	0.003	1.8428	0.0011
374	44.394	0.023	10.184	0.003	1.8406	0.0011
375	43.610	0.022	10.004	0.003	1.8081	0.0011
376	44.382	0.023	10.181	0.003	1.8401	0.0011
377	43.534	0.022	9.987	0.003	1.8049	0.0011
378	43.563	0.022	9.994	0.003	1.8062	0.0011
379	44.432	0.023	10.193	0.003	1.8422	0.0011
380	44.360	0.023	10.176	0.003	1.8392	0.0011
381	44.254	0.023	10.152	0.003	1.8348	0.0011
382	43.558	0.022	9.992	0.003	1.8059	0.0011
383	44.427	0.023	10.192	0.003	1.8420	0.0011
384	43.594	0.022	10.001	0.003	1.8074	0.0011
385	43.527	0.022	9.985	0.003	1.8046	0.0011
386	44.484	0.023	10.205	0.003	1.8443	0.0011
387	44.406	0.023	10.187	0.003	1.8411	0.0011
388	44.429	0.023	10.192	0.003	1.8420	0.0011
389	44.427	0.023	10.192	0.003	1.8420	0.0011
390	43.541	0.022	9.988	0.003	1.8052	0.0011
391	44.403	0.023	10.186	0.003	1.8410	0.0011
392	43.572	0.022	9.995	0.003	1.8065	0.0011
393	43.537	0.022	9.988	0.003	1.8051	0.0011
394	43.598	0.022	10.001	0.003	1.8076	0.0011
395	43.548	0.022	9.990	0.003	1.8055	0.0011
396	44.375	0.023	10.180	0.003	1.8398	0.0011
397	44.451	0.023	10.197	0.003	1.8430	0.0011
398	43.560	0.022	9.993	0.003	1.8060	0.0011
399	44.276	0.023	10.157	0.003	1.8357	0.0011
400	44.386	0.023	10.182	0.003	1.8403	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
401	44.420	0.023	10.190	0.003	1.8417	0.0011
402	44.424	0.023	10.191	0.003	1.8418	0.0011
403	44.429	0.023	10.192	0.003	1.8420	0.0011
404	43.544	0.022	9.989	0.003	1.8054	0.0011
405	44.441	0.023	10.195	0.003	1.8426	0.0011
406	44.438	0.023	10.194	0.003	1.8424	0.0011
407	43.492	0.022	9.977	0.003	1.8032	0.0011
408	43.527	0.022	9.985	0.003	1.8046	0.0011
409	43.580	0.022	9.997	0.003	1.8069	0.0011
410	44.460	0.023	10.199	0.003	1.8433	0.0011
411	44.399	0.023	10.185	0.003	1.8408	0.0011
412	43.598	0.022	10.001	0.003	1.8076	0.0011
413	44.460	0.023	10.199	0.003	1.8433	0.0011
414	43.579	0.022	9.997	0.003	1.8068	0.0011
415	44.412	0.023	10.188	0.003	1.8413	0.0011
416	44.415	0.023	10.189	0.003	1.8415	0.0011
417	43.496	0.022	9.978	0.003	1.8034	0.0011
418	44.375	0.023	10.180	0.003	1.8398	0.0011
419	43.542	0.022	9.989	0.003	1.8053	0.0011
420	43.561	0.022	9.993	0.003	1.8061	0.0011
421	44.379	0.023	10.181	0.003	1.8400	0.0011
422	43.606	0.022	10.003	0.003	1.8079	0.0011
423	44.422	0.023	10.191	0.003	1.8418	0.0011
424	43.548	0.022	9.990	0.003	1.8055	0.0011
425	44.429	0.023	10.192	0.003	1.8420	0.0011
426	44.474	0.023	10.202	0.003	1.8439	0.0011
427	43.506	0.022	9.980	0.003	1.8038	0.0011
428	43.577	0.022	9.997	0.003	1.8067	0.0011
429	44.436	0.023	10.194	0.003	1.8423	0.0011
430	44.354	0.023	10.175	0.003	1.8390	0.0011
431	44.379	0.023	10.181	0.003	1.8400	0.0011
432	44.256	0.023	10.152	0.003	1.8349	0.0011
433	43.480	0.022	9.974	0.003	1.8027	0.0011
434	44.488	0.023	10.206	0.003	1.8445	0.0011
435	43.573	0.022	9.996	0.003	1.8066	0.0011
436	43.570	0.022	9.995	0.003	1.8064	0.0011
437	44.398	0.023	10.185	0.003	1.8408	0.0011
438	43.551	0.022	9.991	0.003	1.8057	0.0011
439	44.439	0.023	10.194	0.003	1.8425	0.0011
440	43.553	0.022	9.991	0.003	1.8057	0.0011
441	43.513	0.022	9.982	0.003	1.8041	0.0011
442	44.479	0.023	10.204	0.003	1.8441	0.0011
443	44.408	0.023	10.187	0.003	1.8412	0.0011
444	44.413	0.023	10.189	0.003	1.8414	0.0011
445	44.415	0.023	10.189	0.003	1.8415	0.0011
446	43.511	0.022	9.982	0.003	1.8040	0.0011
447	43.598	0.022	10.001	0.003	1.8076	0.0011
448	44.412	0.023	10.188	0.003	1.8413	0.0011
449	43.610	0.022	10.004	0.003	1.8081	0.0011
450	44.410	0.023	10.188	0.003	1.8413	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
451	44.391	0.023	10.183	0.003	1.8405	0.0011
452	43.586	0.022	9.999	0.003	1.8071	0.0011
453	43.580	0.022	9.997	0.003	1.8069	0.0011
454	43.565	0.022	9.994	0.003	1.8062	0.0011
455	43.509	0.022	9.981	0.003	1.8039	0.0011
456	43.568	0.022	9.995	0.003	1.8064	0.0011
457	44.403	0.023	10.186	0.003	1.8410	0.0011
458	44.489	0.023	10.206	0.003	1.8446	0.0011
459	43.535	0.022	9.987	0.003	1.8050	0.0011
460	43.532	0.022	9.986	0.003	1.8049	0.0011
461	43.605	0.022	10.003	0.003	1.8079	0.0011
462	43.587	0.022	9.999	0.003	1.8072	0.0011
463	43.516	0.022	9.983	0.003	1.8042	0.0011
464	43.411	0.022	9.959	0.003	1.7998	0.0011
465	44.413	0.023	10.189	0.003	1.8414	0.0011
466	43.553	0.022	9.991	0.003	1.8057	0.0011
467	43.369	0.022	9.949	0.003	1.7981	0.0011
468	43.582	0.022	9.998	0.003	1.8069	0.0011
469	43.548	0.022	9.990	0.003	1.8055	0.0011
470	44.418	0.023	10.190	0.003	1.8416	0.0011
471	43.546	0.022	9.990	0.003	1.8054	0.0011
472	44.401	0.023	10.186	0.003	1.8409	0.0011
473	44.453	0.023	10.198	0.003	1.8431	0.0011
474	44.405	0.023	10.187	0.003	1.8410	0.0011
475	44.304	0.023	10.164	0.003	1.8369	0.0011
476	44.469	0.023	10.201	0.003	1.8437	0.0011
477	43.556	0.022	9.992	0.003	1.8059	0.0011
478	44.434	0.023	10.193	0.003	1.8423	0.0011
479	43.570	0.022	9.995	0.003	1.8064	0.0011
480	44.436	0.023	10.194	0.003	1.8423	0.0011
481	43.605	0.022	10.003	0.003	1.8079	0.0011
482	43.496	0.022	9.978	0.003	1.8034	0.0011
483	43.556	0.022	9.992	0.003	1.8059	0.0011
484	44.432	0.023	10.193	0.003	1.8422	0.0011
485	43.542	0.022	9.989	0.003	1.8053	0.0011
486	44.467	0.023	10.201	0.003	1.8436	0.0011
487	44.425	0.023	10.191	0.003	1.8419	0.0011
488	43.558	0.022	9.992	0.003	1.8059	0.0011
489	44.389	0.023	10.183	0.003	1.8404	0.0011
490	43.587	0.022	9.999	0.003	1.8072	0.0011
491	43.532	0.022	9.986	0.003	1.8049	0.0011
492	44.455	0.023	10.198	0.003	1.8431	0.0011
493	43.530	0.022	9.986	0.003	1.8048	0.0011
494	43.527	0.022	9.985	0.003	1.8046	0.0011
495	43.598	0.022	10.001	0.003	1.8076	0.0011
496	44.327	0.023	10.169	0.003	1.8378	0.0011
497	43.490	0.022	9.977	0.003	1.8031	0.0011
498	43.535	0.022	9.987	0.003	1.8050	0.0011
499	44.425	0.023	10.191	0.003	1.8419	0.0011
500	44.373	0.023	10.179	0.003	1.8397	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
501	44.436	0.023	10.194	0.003	1.8423	0.0011
502	44.413	0.023	10.189	0.003	1.8414	0.0011
503	44.422	0.023	10.191	0.003	1.8418	0.0011
504	44.396	0.023	10.185	0.003	1.8407	0.0011
505	43.608	0.022	10.004	0.003	1.8080	0.0011
506	44.394	0.023	10.184	0.003	1.8406	0.0011
507	43.575	0.022	9.996	0.003	1.8067	0.0011
508	44.460	0.023	10.199	0.003	1.8433	0.0011
509	43.539	0.022	9.988	0.003	1.8051	0.0011
510	44.415	0.023	10.189	0.003	1.8415	0.0011
511	43.554	0.022	9.992	0.003	1.8058	0.0011
512	44.470	0.023	10.202	0.003	1.8438	0.0011
513	44.368	0.023	10.178	0.003	1.8395	0.0011
514	43.610	0.022	10.004	0.003	1.8081	0.0011
515	43.567	0.022	9.994	0.003	1.8063	0.0011
516	43.551	0.022	9.991	0.003	1.8056	0.0011
517	43.563	0.022	9.994	0.003	1.8062	0.0011
518	43.548	0.022	9.990	0.003	1.8055	0.0011
519	44.434	0.023	10.193	0.003	1.8423	0.0011
520	43.594	0.022	10.001	0.003	1.8074	0.0011
521	44.202	0.023	10.140	0.003	1.8326	0.0011
522	43.620	0.022	10.007	0.003	1.8085	0.0011
523	44.453	0.023	10.198	0.003	1.8431	0.0011
524	44.415	0.023	10.189	0.003	1.8415	0.0011
525	44.470	0.023	10.202	0.003	1.8438	0.0011
526	43.554	0.022	9.992	0.003	1.8058	0.0011
527	44.347	0.023	10.173	0.003	1.8387	0.0011
528	44.318	0.023	10.167	0.003	1.8375	0.0011
529	44.446	0.023	10.196	0.003	1.8428	0.0011
530	43.475	0.022	9.973	0.003	1.8025	0.0011
531	43.606	0.022	10.003	0.003	1.8079	0.0011
532	44.382	0.023	10.181	0.003	1.8401	0.0011
533	44.418	0.023	10.190	0.003	1.8416	0.0011
534	43.599	0.022	10.002	0.003	1.8077	0.0011
535	44.446	0.023	10.196	0.003	1.8428	0.0011
536	44.389	0.023	10.183	0.003	1.8404	0.0011
537	44.443	0.023	10.195	0.003	1.8426	0.0011
538	44.431	0.023	10.193	0.003	1.8421	0.0011
539	44.415	0.023	10.189	0.003	1.8415	0.0011
540	44.458	0.023	10.199	0.003	1.8433	0.0011
541	44.420	0.023	10.190	0.003	1.8417	0.0011
542	44.432	0.023	10.193	0.003	1.8422	0.0011
543	43.605	0.022	10.003	0.003	1.8079	0.0011
544	43.530	0.022	9.986	0.003	1.8048	0.0011
545	43.570	0.022	9.995	0.003	1.8064	0.0011
546	43.530	0.022	9.986	0.003	1.8048	0.0011
547	43.582	0.022	9.998	0.003	1.8069	0.0011
548	44.437	0.023	10.194	0.003	1.8424	0.0011
549	44.420	0.023	10.190	0.003	1.8417	0.0011
550	44.420	0.023	10.190	0.003	1.8417	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
551	44.434	0.023	10.193	0.003	1.8423	0.0011
552	44.392	0.023	10.184	0.003	1.8405	0.0011
553	44.424	0.023	10.191	0.003	1.8418	0.0011
554	44.418	0.023	10.190	0.003	1.8416	0.0011
555	43.573	0.022	9.996	0.003	1.8066	0.0011
556	44.424	0.023	10.191	0.003	1.8418	0.0011
557	44.382	0.023	10.181	0.003	1.8401	0.0011
558	43.504	0.022	9.980	0.003	1.8037	0.0011
559	44.436	0.023	10.194	0.003	1.8423	0.0011
560	43.573	0.022	9.996	0.003	1.8066	0.0011
561	44.444	0.023	10.196	0.003	1.8427	0.0011
562	44.462	0.023	10.200	0.003	1.8434	0.0011
563	44.424	0.023	10.191	0.003	1.8418	0.0011
564	43.554	0.022	9.992	0.003	1.8058	0.0011
565	44.377	0.023	10.180	0.003	1.8399	0.0011
566	43.606	0.022	10.003	0.003	1.8079	0.0011
567	43.535	0.022	9.987	0.003	1.8050	0.0011
568	44.418	0.023	10.190	0.003	1.8416	0.0011
569	43.572	0.022	9.995	0.003	1.8065	0.0011
570	44.398	0.023	10.185	0.003	1.8408	0.0011
571	43.535	0.022	9.987	0.003	1.8050	0.0011
572	43.525	0.022	9.985	0.003	1.8046	0.0011
573	44.398	0.023	10.185	0.003	1.8408	0.0011
574	44.392	0.023	10.184	0.003	1.8405	0.0011
575	43.551	0.022	9.991	0.003	1.8056	0.0011
576	43.610	0.022	10.004	0.003	1.8081	0.0011
577	43.572	0.022	9.996	0.003	1.8065	0.0011
578	43.525	0.022	9.985	0.003	1.8046	0.0011
579	43.562	0.022	9.993	0.003	1.8061	0.0011
580	44.356	0.023	10.176	0.003	1.8390	0.0011
581	43.555	0.022	9.992	0.003	1.8058	0.0011
582	44.429	0.023	10.192	0.003	1.8421	0.0011
583	44.381	0.023	10.181	0.003	1.8401	0.0011
584	43.531	0.022	9.986	0.003	1.8048	0.0011
585	44.448	0.023	10.197	0.003	1.8429	0.0011
586	43.560	0.022	9.993	0.003	1.8060	0.0011
587	44.384	0.023	10.182	0.003	1.8402	0.0011
588	43.581	0.022	9.998	0.003	1.8069	0.0011
589	43.515	0.022	9.982	0.003	1.8042	0.0011
590	43.369	0.022	9.949	0.003	1.7981	0.0011
591	44.395	0.023	10.184	0.003	1.8406	0.0011
592	44.298	0.023	10.162	0.003	1.8366	0.0011
593	44.410	0.023	10.188	0.003	1.8413	0.0011
594	44.427	0.023	10.192	0.003	1.8420	0.0011
595	44.431	0.023	10.193	0.003	1.8421	0.0011
596	44.334	0.023	10.170	0.003	1.8381	0.0011
597	43.569	0.022	9.995	0.003	1.8064	0.0011
598	43.605	0.022	10.003	0.003	1.8079	0.0011
599	44.403	0.023	10.186	0.003	1.8410	0.0011
600	44.471	0.023	10.202	0.003	1.8438	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
601	43.531	0.022	9.986	0.003	1.8048	0.0011
602	44.443	0.023	10.195	0.003	1.8426	0.0011
603	43.570	0.022	9.995	0.003	1.8065	0.0011
604	44.401	0.023	10.186	0.003	1.8409	0.0011
605	44.294	0.023	10.161	0.003	1.8365	0.0011
606	43.570	0.022	9.995	0.003	1.8065	0.0011
607	43.529	0.022	9.986	0.003	1.8047	0.0011
608	44.457	0.023	10.199	0.003	1.8432	0.0011
609	43.558	0.022	9.992	0.003	1.8060	0.0011
610	44.360	0.023	10.176	0.003	1.8392	0.0011
611	43.574	0.022	9.996	0.003	1.8066	0.0011
612	43.591	0.022	10.000	0.003	1.8073	0.0011
613	44.433	0.023	10.193	0.003	1.8422	0.0011
614	44.427	0.023	10.192	0.003	1.8420	0.0011
615	44.427	0.023	10.192	0.003	1.8420	0.0011
616	44.419	0.023	10.190	0.003	1.8416	0.0011
617	44.455	0.023	10.198	0.003	1.8431	0.0011
618	44.389	0.023	10.183	0.003	1.8404	0.0011
619	44.393	0.023	10.184	0.003	1.8406	0.0011
620	43.614	0.022	10.005	0.003	1.8082	0.0011
621	44.401	0.023	10.186	0.003	1.8409	0.0011
622	44.445	0.023	10.196	0.003	1.8427	0.0011
623	44.391	0.023	10.183	0.003	1.8405	0.0011
624	44.367	0.023	10.178	0.003	1.8395	0.0011
625	44.346	0.023	10.173	0.003	1.8386	0.0011
626	43.434	0.022	9.964	0.003	1.8008	0.0011
627	44.408	0.023	10.187	0.003	1.8412	0.0011
628	43.634	0.022	10.010	0.003	1.8091	0.0011
629	43.525	0.022	9.985	0.003	1.8046	0.0011
630	44.427	0.023	10.192	0.003	1.8420	0.0011
631	44.415	0.023	10.189	0.003	1.8415	0.0011
632	43.595	0.022	10.001	0.003	1.8075	0.0011
633	43.584	0.022	9.998	0.003	1.8070	0.0011
634	44.438	0.023	10.194	0.003	1.8424	0.0011
635	44.401	0.023	10.186	0.003	1.8409	0.0011
636	44.455	0.023	10.198	0.003	1.8431	0.0011
637	43.508	0.022	9.981	0.003	1.8039	0.0011
638	44.400	0.023	10.185	0.003	1.8408	0.0011
639	43.593	0.022	10.000	0.003	1.8074	0.0011
640	43.572	0.022	9.996	0.003	1.8065	0.0011
641	43.551	0.022	9.991	0.003	1.8057	0.0011
642	44.415	0.023	10.189	0.003	1.8415	0.0011
643	43.541	0.022	9.988	0.003	1.8052	0.0011
644	44.396	0.023	10.185	0.003	1.8407	0.0011
645	44.256	0.023	10.152	0.003	1.8349	0.0011
646	43.550	0.022	9.990	0.003	1.8056	0.0011
647	44.448	0.023	10.197	0.003	1.8429	0.0011
648	43.550	0.022	9.990	0.003	1.8056	0.0011
649	44.398	0.023	10.185	0.003	1.8408	0.0011
650	44.490	0.023	10.206	0.003	1.8446	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
651	44.405	0.023	10.187	0.003	1.8411	0.0011
652	44.403	0.023	10.186	0.003	1.8410	0.0011
653	43.584	0.022	9.998	0.003	1.8070	0.0011
654	44.400	0.023	10.185	0.003	1.8408	0.0011
655	43.615	0.022	10.005	0.003	1.8083	0.0011
656	44.427	0.023	10.192	0.003	1.8420	0.0011
657	44.403	0.023	10.186	0.003	1.8410	0.0011
658	44.422	0.023	10.191	0.003	1.8418	0.0011
659	44.466	0.023	10.201	0.003	1.8436	0.0011
660	43.563	0.022	9.994	0.003	1.8062	0.0011
661	44.401	0.023	10.186	0.003	1.8409	0.0011
662	44.462	0.023	10.200	0.003	1.8434	0.0011
663	44.339	0.023	10.172	0.003	1.8383	0.0011
664	44.455	0.023	10.198	0.003	1.8431	0.0011
665	43.553	0.022	9.991	0.003	1.8057	0.0011
666	44.460	0.023	10.199	0.003	1.8434	0.0011
667	44.398	0.023	10.185	0.003	1.8408	0.0011
668	44.472	0.023	10.202	0.003	1.8439	0.0011
669	44.389	0.023	10.183	0.003	1.8404	0.0011
670	44.421	0.023	10.190	0.003	1.8417	0.0011
671	43.579	0.022	9.997	0.003	1.8068	0.0011
672	44.389	0.023	10.183	0.003	1.8404	0.0011
673	44.436	0.023	10.194	0.003	1.8424	0.0011
674	43.572	0.022	9.996	0.003	1.8065	0.0011
675	43.564	0.022	9.994	0.003	1.8062	0.0011
676	43.538	0.022	9.988	0.003	1.8051	0.0011
677	44.443	0.023	10.195	0.003	1.8426	0.0011
678	43.505	0.022	9.980	0.003	1.8037	0.0011
679	44.407	0.023	10.187	0.003	1.8411	0.0011
680	43.512	0.022	9.982	0.003	1.8040	0.0011
681	44.452	0.023	10.197	0.003	1.8430	0.0011
682	43.569	0.022	9.995	0.003	1.8064	0.0011
683	44.445	0.023	10.196	0.003	1.8427	0.0011
684	44.417	0.023	10.189	0.003	1.8416	0.0011
685	44.383	0.023	10.182	0.003	1.8401	0.0011
686	43.555	0.022	9.992	0.003	1.8058	0.0011
687	43.638	0.022	10.011	0.003	1.8093	0.0011
688	43.553	0.022	9.991	0.003	1.8057	0.0011
689	44.407	0.023	10.187	0.003	1.8411	0.0011
690	44.448	0.023	10.197	0.003	1.8429	0.0011
691	43.520	0.022	9.984	0.003	1.8044	0.0011
692	44.433	0.023	10.193	0.003	1.8422	0.0011
693	44.448	0.023	10.197	0.003	1.8429	0.0011
694	43.541	0.022	9.988	0.003	1.8052	0.0011
695	43.588	0.022	9.999	0.003	1.8072	0.0011
696	43.517	0.022	9.983	0.003	1.8042	0.0011
697	43.562	0.022	9.993	0.003	1.8061	0.0011
698	44.445	0.023	10.196	0.003	1.8427	0.0011
699	44.381	0.023	10.181	0.003	1.8401	0.0011
700	43.600	0.022	10.002	0.003	1.8077	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
701	43.593	0.022	10.000	0.003	1.8074	0.0011
702	43.474	0.022	9.973	0.003	1.8024	0.0011
703	43.605	0.022	10.003	0.003	1.8079	0.0011
704	44.353	0.023	10.175	0.003	1.8389	0.0011
705	44.417	0.023	10.189	0.003	1.8416	0.0011
706	43.581	0.022	9.998	0.003	1.8069	0.0011
707	44.393	0.023	10.184	0.003	1.8406	0.0011
708	44.455	0.023	10.198	0.003	1.8431	0.0011
709	43.571	0.022	9.995	0.003	1.8065	0.0011
710	43.560	0.022	9.993	0.003	1.8060	0.0011
711	43.557	0.022	9.992	0.003	1.8059	0.0011
712	44.438	0.023	10.194	0.003	1.8424	0.0011
713	44.429	0.023	10.192	0.003	1.8421	0.0011
714	44.400	0.023	10.185	0.003	1.8408	0.0011
715	43.526	0.022	9.985	0.003	1.8046	0.0011
716	43.591	0.022	10.000	0.003	1.8073	0.0011
717	44.414	0.023	10.189	0.003	1.8414	0.0011
718	44.412	0.023	10.188	0.003	1.8414	0.0011
719	44.473	0.023	10.202	0.003	1.8439	0.0011
720	44.388	0.023	10.183	0.003	1.8403	0.0011
721	43.543	0.022	9.989	0.003	1.8053	0.0011
722	43.572	0.022	9.996	0.003	1.8065	0.0011
723	43.593	0.022	10.000	0.003	1.8074	0.0011
724	43.538	0.022	9.988	0.003	1.8051	0.0011
725	43.470	0.022	9.972	0.003	1.8023	0.0011
726	44.371	0.023	10.179	0.003	1.8396	0.0011
727	43.550	0.022	9.990	0.003	1.8056	0.0011
728	43.598	0.022	10.002	0.003	1.8076	0.0011
729	43.569	0.022	9.995	0.003	1.8064	0.0011
730	43.506	0.022	9.981	0.003	1.8038	0.0011
731	43.572	0.022	9.996	0.003	1.8065	0.0011
732	44.483	0.023	10.205	0.003	1.8443	0.0011
733	44.383	0.023	10.182	0.003	1.8401	0.0011
734	44.459	0.023	10.199	0.003	1.8433	0.0011
735	43.560	0.022	9.993	0.003	1.8060	0.0011
736	44.396	0.023	10.185	0.003	1.8407	0.0011
737	43.569	0.022	9.995	0.003	1.8064	0.0011
738	43.591	0.022	10.000	0.003	1.8073	0.0011
739	43.569	0.022	9.995	0.003	1.8064	0.0011
740	44.384	0.023	10.182	0.003	1.8402	0.0011
741	43.609	0.022	10.004	0.003	1.8080	0.0011
742	44.360	0.023	10.176	0.003	1.8392	0.0011
743	44.440	0.023	10.195	0.003	1.8425	0.0011
744	44.445	0.023	10.196	0.003	1.8427	0.0011
745	43.548	0.022	9.990	0.003	1.8055	0.0011
746	44.379	0.023	10.181	0.003	1.8400	0.0011
747	43.536	0.022	9.987	0.003	1.8050	0.0011
748	43.607	0.022	10.004	0.003	1.8080	0.0011
749	43.574	0.022	9.996	0.003	1.8066	0.0011
750	43.529	0.022	9.986	0.003	1.8047	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
751	44.448	0.023	10.197	0.003	1.8429	0.0011
752	43.531	0.022	9.986	0.003	1.8048	0.0011
753	44.431	0.023	10.193	0.003	1.8421	0.0011
754	43.512	0.022	9.982	0.003	1.8040	0.0011
755	44.422	0.023	10.191	0.003	1.8418	0.0011
756	43.571	0.022	9.995	0.003	1.8065	0.0011
757	44.421	0.023	10.190	0.003	1.8417	0.0011
758	43.551	0.022	9.991	0.003	1.8057	0.0011
759	44.407	0.023	10.187	0.003	1.8411	0.0011
760	44.457	0.023	10.199	0.003	1.8432	0.0011
761	44.409	0.023	10.187	0.003	1.8412	0.0011
762	44.341	0.023	10.172	0.003	1.8384	0.0011
763	43.565	0.022	9.994	0.003	1.8062	0.0011
764	43.541	0.022	9.988	0.003	1.8052	0.0011
765	43.567	0.022	9.994	0.003	1.8063	0.0011
766	43.565	0.022	9.994	0.003	1.8062	0.0011
767	43.517	0.022	9.983	0.003	1.8042	0.0011
768	43.583	0.022	9.998	0.003	1.8070	0.0011
769	44.514	0.023	10.212	0.003	1.8456	0.0011
770	44.400	0.023	10.186	0.003	1.8409	0.0011
771	43.560	0.022	9.993	0.003	1.8060	0.0011
772	44.501	0.023	10.209	0.003	1.8450	0.0011
773	43.550	0.022	9.990	0.003	1.8056	0.0011
774	44.468	0.023	10.201	0.003	1.8437	0.0011
775	44.501	0.023	10.209	0.003	1.8450	0.0011
776	44.411	0.023	10.188	0.003	1.8413	0.0011
777	44.369	0.023	10.178	0.003	1.8396	0.0011
778	43.605	0.022	10.003	0.003	1.8079	0.0011
779	43.540	0.022	9.988	0.003	1.8052	0.0011
780	43.567	0.022	9.994	0.003	1.8063	0.0011
781	44.504	0.023	10.209	0.003	1.8452	0.0011
782	44.447	0.023	10.196	0.003	1.8428	0.0011
783	43.529	0.022	9.986	0.003	1.8047	0.0011
784	44.386	0.023	10.182	0.003	1.8403	0.0011
785	43.527	0.022	9.985	0.003	1.8047	0.0011
786	43.545	0.022	9.989	0.003	1.8054	0.0011
787	43.618	0.022	10.006	0.003	1.8084	0.0011
788	43.526	0.022	9.985	0.003	1.8046	0.0011
789	44.428	0.023	10.192	0.003	1.8420	0.0011
790	43.614	0.022	10.005	0.003	1.8083	0.0011
791	43.585	0.022	9.998	0.003	1.8070	0.0011
792	44.442	0.023	10.195	0.003	1.8426	0.0011
793	44.454	0.023	10.198	0.003	1.8431	0.0011
794	43.578	0.022	9.997	0.003	1.8068	0.0011
795	43.521	0.022	9.984	0.003	1.8044	0.0011
796	44.468	0.023	10.201	0.003	1.8437	0.0011
797	44.395	0.023	10.184	0.003	1.8406	0.0011
798	43.652	0.022	10.014	0.003	1.8098	0.0011
799	44.381	0.023	10.181	0.003	1.8401	0.0011
800	43.533	0.022	9.987	0.003	1.8049	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
801	43.621	0.022	10.007	0.003	1.8086	0.0011
802	43.553	0.022	9.991	0.003	1.8058	0.0011
803	44.383	0.023	10.182	0.003	1.8401	0.0011
804	43.592	0.022	10.000	0.003	1.8073	0.0011
805	43.550	0.022	9.990	0.003	1.8056	0.0011
806	43.486	0.022	9.976	0.003	1.8030	0.0011
807	43.521	0.022	9.984	0.003	1.8044	0.0011
808	43.611	0.022	10.004	0.003	1.8081	0.0011
809	44.417	0.023	10.190	0.003	1.8416	0.0011
810	44.487	0.023	10.205	0.003	1.8444	0.0011
811	44.452	0.023	10.197	0.003	1.8430	0.0011
812	44.454	0.023	10.198	0.003	1.8431	0.0011
813	44.443	0.023	10.195	0.003	1.8427	0.0011
814	43.560	0.022	9.993	0.003	1.8060	0.0011
815	44.508	0.023	10.210	0.003	1.8453	0.0011
816	43.566	0.022	9.994	0.003	1.8063	0.0011
817	43.579	0.022	9.997	0.003	1.8068	0.0011
818	44.450	0.023	10.197	0.003	1.8429	0.0011
819	43.576	0.022	9.996	0.003	1.8067	0.0011
820	44.378	0.023	10.180	0.003	1.8399	0.0011
821	43.612	0.022	10.005	0.003	1.8082	0.0011
822	44.428	0.023	10.192	0.003	1.8420	0.0011
823	44.443	0.023	10.195	0.003	1.8427	0.0011
824	43.593	0.022	10.000	0.003	1.8074	0.0011
825	43.552	0.022	9.991	0.003	1.8057	0.0011
826	43.595	0.022	10.001	0.003	1.8075	0.0011
827	43.576	0.022	9.996	0.003	1.8067	0.0011
828	43.588	0.022	9.999	0.003	1.8072	0.0011
829	44.416	0.023	10.189	0.003	1.8415	0.0011
830	44.452	0.023	10.197	0.003	1.8430	0.0011
831	44.392	0.023	10.184	0.003	1.8405	0.0011
832	44.457	0.023	10.199	0.003	1.8432	0.0011
833	44.414	0.023	10.189	0.003	1.8414	0.0011
834	44.346	0.023	10.173	0.003	1.8386	0.0011
835	43.562	0.022	9.993	0.003	1.8061	0.0011
836	44.421	0.023	10.190	0.003	1.8417	0.0011
837	43.583	0.022	9.998	0.003	1.8070	0.0011
838	44.393	0.023	10.184	0.003	1.8406	0.0011
839	43.476	0.022	9.973	0.003	1.8025	0.0011
840	43.571	0.022	9.995	0.003	1.8065	0.0011
841	43.609	0.022	10.004	0.003	1.8081	0.0011
842	43.557	0.022	9.992	0.003	1.8059	0.0011
843	43.507	0.022	9.981	0.003	1.8038	0.0011
844	43.621	0.022	10.007	0.003	1.8086	0.0011
845	44.412	0.023	10.188	0.003	1.8414	0.0011
846	43.595	0.022	10.001	0.003	1.8075	0.0011
847	43.600	0.022	10.002	0.003	1.8077	0.0011
848	44.402	0.023	10.186	0.003	1.8409	0.0011
849	44.452	0.023	10.197	0.003	1.8430	0.0011
850	43.583	0.022	9.998	0.003	1.8070	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
851	43.553	0.022	9.991	0.003	1.8058	0.0011
852	43.583	0.022	9.998	0.003	1.8070	0.0011
853	43.534	0.022	9.987	0.003	1.8050	0.0011
854	44.438	0.023	10.194	0.003	1.8424	0.0011
855	43.538	0.022	9.988	0.003	1.8051	0.0011
856	43.588	0.022	9.999	0.003	1.8072	0.0011
857	43.574	0.022	9.996	0.003	1.8066	0.0011
858	44.447	0.023	10.196	0.003	1.8428	0.0011
859	44.411	0.023	10.188	0.003	1.8413	0.0011
860	44.322	0.023	10.168	0.003	1.8376	0.0011
861	44.430	0.023	10.192	0.003	1.8421	0.0011
862	43.569	0.022	9.995	0.003	1.8064	0.0011
863	44.433	0.023	10.193	0.003	1.8422	0.0011
864	43.621	0.022	10.007	0.003	1.8086	0.0011
865	43.545	0.022	9.989	0.003	1.8054	0.0011
866	44.449	0.023	10.197	0.003	1.8429	0.0011
867	43.643	0.022	10.012	0.003	1.8095	0.0011
868	44.440	0.023	10.195	0.003	1.8425	0.0011
869	44.445	0.023	10.196	0.003	1.8427	0.0011
870	44.447	0.023	10.196	0.003	1.8428	0.0011
871	44.497	0.023	10.208	0.003	1.8449	0.0011
872	44.428	0.023	10.192	0.003	1.8420	0.0011
873	44.492	0.023	10.207	0.003	1.8447	0.0011
874	43.598	0.022	10.002	0.003	1.8076	0.0011
875	44.416	0.023	10.189	0.003	1.8415	0.0011
876	43.607	0.022	10.004	0.003	1.8080	0.0011
877	44.464	0.023	10.200	0.003	1.8435	0.0011
878	43.571	0.022	9.995	0.003	1.8065	0.0011
879	44.398	0.023	10.185	0.003	1.8408	0.0011
880	43.611	0.022	10.004	0.003	1.8081	0.0011
881	43.562	0.022	9.993	0.003	1.8061	0.0011
882	44.398	0.023	10.185	0.003	1.8408	0.0011
883	43.623	0.022	10.007	0.003	1.8086	0.0011
884	44.400	0.023	10.186	0.003	1.8409	0.0011
885	44.454	0.023	10.198	0.003	1.8431	0.0011
886	44.443	0.023	10.195	0.003	1.8427	0.0011
887	43.571	0.022	9.995	0.003	1.8065	0.0011
888	44.411	0.023	10.188	0.003	1.8413	0.0011
889	44.405	0.023	10.187	0.003	1.8411	0.0011
890	44.416	0.023	10.189	0.003	1.8415	0.0011
891	43.607	0.022	10.004	0.003	1.8080	0.0011
892	43.477	0.022	9.974	0.003	1.8026	0.0011
893	44.407	0.023	10.187	0.003	1.8411	0.0011
894	43.604	0.022	10.003	0.003	1.8078	0.0011
895	43.597	0.022	10.001	0.003	1.8075	0.0011
896	43.562	0.022	9.993	0.003	1.8061	0.0011
897	43.553	0.022	9.991	0.003	1.8058	0.0011
898	43.586	0.022	9.999	0.003	1.8071	0.0011
899	44.392	0.023	10.184	0.003	1.8405	0.0011
900	43.560	0.022	9.993	0.003	1.8060	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
901	43.578	0.022	9.997	0.003	1.8068	0.0011
902	43.597	0.022	10.001	0.003	1.8075	0.0011
903	44.404	0.023	10.186	0.003	1.8410	0.0011
904	43.595	0.022	10.001	0.003	1.8075	0.0011
905	43.637	0.022	10.010	0.003	1.8092	0.0011
906	44.428	0.023	10.192	0.003	1.8420	0.0011
907	43.522	0.022	9.984	0.003	1.8045	0.0011
908	44.499	0.023	10.208	0.003	1.8450	0.0011
909	44.459	0.023	10.199	0.003	1.8433	0.0011
910	43.588	0.022	9.999	0.003	1.8072	0.0011
911	44.416	0.023	10.189	0.003	1.8415	0.0011
912	43.595	0.022	10.001	0.003	1.8075	0.0011
913	44.454	0.023	10.198	0.003	1.8431	0.0011
914	43.593	0.022	10.000	0.003	1.8074	0.0011
915	43.581	0.022	9.998	0.003	1.8069	0.0011
916	43.541	0.022	9.989	0.003	1.8052	0.0011
917	44.426	0.023	10.191	0.003	1.8419	0.0011
918	44.421	0.023	10.190	0.003	1.8417	0.0011
919	43.585	0.022	9.998	0.003	1.8070	0.0011
920	43.508	0.022	9.981	0.003	1.8039	0.0011
921	44.220	0.023	10.144	0.003	1.8334	0.0011
922	43.574	0.022	9.996	0.003	1.8066	0.0011
923	43.566	0.022	9.994	0.003	1.8063	0.0011
924	44.431	0.023	10.193	0.003	1.8422	0.0011
925	44.407	0.023	10.187	0.003	1.8411	0.0011
926	43.618	0.022	10.006	0.003	1.8084	0.0011
927	44.421	0.023	10.190	0.003	1.8417	0.0011
928	44.424	0.023	10.191	0.003	1.8419	0.0011
929	44.407	0.023	10.187	0.003	1.8411	0.0011
930	43.531	0.022	9.986	0.003	1.8048	0.0011
931	43.619	0.022	10.006	0.003	1.8085	0.0011
932	44.402	0.023	10.186	0.003	1.8409	0.0011
933	44.393	0.023	10.184	0.003	1.8406	0.0011
934	43.592	0.022	10.000	0.003	1.8073	0.0011
935	43.567	0.022	9.994	0.003	1.8063	0.0011
936	44.404	0.023	10.186	0.003	1.8410	0.0011
937	43.462	0.022	9.970	0.003	1.8019	0.0011
938	44.414	0.023	10.189	0.003	1.8414	0.0011
939	44.433	0.023	10.193	0.003	1.8422	0.0011
940	44.390	0.023	10.183	0.003	1.8404	0.0011
941	43.602	0.022	10.002	0.003	1.8078	0.0011
942	44.395	0.023	10.184	0.003	1.8406	0.0011
943	43.519	0.022	9.983	0.003	1.8043	0.0011
944	44.480	0.023	10.204	0.003	1.8442	0.0011
945	43.524	0.022	9.985	0.003	1.8045	0.0011
946	44.457	0.023	10.199	0.003	1.8432	0.0011
947	43.576	0.022	9.996	0.003	1.8067	0.0011
948	44.424	0.023	10.191	0.003	1.8419	0.0011
949	43.531	0.022	9.986	0.003	1.8048	0.0011
950	43.566	0.022	9.994	0.003	1.8063	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
951	44.428	0.023	10.192	0.003	1.8420	0.0011
952	43.560	0.022	9.993	0.003	1.8060	0.0011
953	43.538	0.022	9.988	0.003	1.8051	0.0011
954	44.423	0.023	10.191	0.003	1.8418	0.0011
955	44.440	0.023	10.195	0.003	1.8425	0.0011
956	44.404	0.023	10.186	0.003	1.8410	0.0011
957	43.588	0.022	9.999	0.003	1.8072	0.0011
958	43.548	0.022	9.990	0.003	1.8055	0.0011
959	44.426	0.023	10.191	0.003	1.8419	0.0011
960	44.412	0.023	10.188	0.003	1.8414	0.0011
961	44.428	0.023	10.192	0.003	1.8420	0.0011
962	44.438	0.023	10.194	0.003	1.8424	0.0011
963	43.557	0.022	9.992	0.003	1.8059	0.0011
964	44.428	0.023	10.192	0.003	1.8420	0.0011
965	43.578	0.022	9.997	0.003	1.8068	0.0011
966	43.579	0.022	9.997	0.003	1.8068	0.0011
967	44.411	0.023	10.188	0.003	1.8413	0.0011
968	43.482	0.022	9.975	0.003	1.8028	0.0011
969	43.574	0.022	9.996	0.003	1.8066	0.0011
970	43.546	0.022	9.990	0.003	1.8055	0.0011
971	44.437	0.023	10.194	0.003	1.8424	0.0011
972	44.423	0.023	10.191	0.003	1.8418	0.0011
973	44.383	0.023	10.182	0.003	1.8401	0.0011
974	43.590	0.022	10.000	0.003	1.8073	0.0011
975	44.423	0.023	10.191	0.003	1.8418	0.0011
976	43.560	0.022	9.993	0.003	1.8060	0.0011
977	44.440	0.023	10.195	0.003	1.8425	0.0011
978	43.562	0.022	9.993	0.003	1.8061	0.0011
979	43.517	0.022	9.983	0.003	1.8042	0.0011
980	43.604	0.022	10.003	0.003	1.8078	0.0011
981	43.550	0.022	9.990	0.003	1.8056	0.0011
982	44.414	0.023	10.189	0.003	1.8414	0.0011
983	43.619	0.022	10.006	0.003	1.8085	0.0011
984	44.369	0.023	10.178	0.003	1.8396	0.0011
985	43.593	0.022	10.000	0.003	1.8074	0.0011
986	44.395	0.023	10.184	0.003	1.8406	0.0011
987	44.405	0.023	10.187	0.003	1.8411	0.0011
988	44.414	0.023	10.189	0.003	1.8414	0.0011
989	44.433	0.023	10.193	0.003	1.8422	0.0011
990	44.412	0.023	10.188	0.003	1.8414	0.0011
991	44.386	0.023	10.182	0.003	1.8403	0.0011
992	43.598	0.022	10.002	0.003	1.8076	0.0011
993	44.409	0.023	10.188	0.003	1.8412	0.0011
994	43.597	0.022	10.001	0.003	1.8075	0.0011
995	43.557	0.022	9.992	0.003	1.8059	0.0011
996	44.305	0.023	10.164	0.003	1.8369	0.0011
997	44.447	0.023	10.196	0.003	1.8428	0.0011
998	44.357	0.023	10.176	0.003	1.8391	0.0011
999	44.445	0.023	10.196	0.003	1.8427	0.0011
1000	43.581	0.022	9.998	0.003	1.8069	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
1001	43.534	0.022	9.987	0.003	1.8050	0.0011
1002	43.555	0.022	9.992	0.003	1.8058	0.0011
1003	44.414	0.023	10.189	0.003	1.8414	0.0011
1004	43.581	0.022	9.998	0.003	1.8069	0.0011
1005	44.398	0.023	10.185	0.003	1.8408	0.0011
1006	43.527	0.022	9.985	0.003	1.8047	0.0011
1007	44.445	0.023	10.196	0.003	1.8427	0.0011
1008	44.464	0.023	10.200	0.003	1.8435	0.0011
1009	43.592	0.022	10.000	0.003	1.8073	0.0011
1010	44.374	0.023	10.180	0.003	1.8398	0.0011
1011	43.578	0.022	9.997	0.003	1.8068	0.0011
1012	44.469	0.023	10.201	0.003	1.8437	0.0011
1013	44.357	0.023	10.176	0.003	1.8391	0.0011
1014	44.475	0.023	10.203	0.003	1.8439	0.0011
1015	44.409	0.023	10.188	0.003	1.8412	0.0011
1016	43.562	0.022	9.993	0.003	1.8061	0.0011
1017	43.566	0.022	9.994	0.003	1.8063	0.0011
1018	44.372	0.023	10.179	0.003	1.8397	0.0011
1019	44.443	0.023	10.195	0.003	1.8427	0.0011
1020	43.463	0.022	9.971	0.003	1.8020	0.0011
1021	44.388	0.023	10.183	0.003	1.8404	0.0011
1022	44.411	0.023	10.188	0.003	1.8413	0.0011
1023	44.431	0.023	10.193	0.003	1.8421	0.0011
1024	43.607	0.022	10.004	0.003	1.8080	0.0011
1025	44.378	0.023	10.180	0.003	1.8399	0.0011
1026	43.607	0.022	10.004	0.003	1.8080	0.0011
1027	44.421	0.023	10.190	0.003	1.8417	0.0011
1028	43.540	0.022	9.988	0.003	1.8052	0.0011
1029	44.449	0.023	10.197	0.003	1.8429	0.0011
1030	43.545	0.022	9.989	0.003	1.8054	0.0011
1031	44.414	0.023	10.189	0.003	1.8414	0.0011
1032	43.595	0.022	10.001	0.003	1.8075	0.0011
1033	43.572	0.022	9.996	0.003	1.8065	0.0011
1034	43.557	0.022	9.992	0.003	1.8059	0.0011
1035	44.404	0.023	10.186	0.003	1.8410	0.0011
1036	43.588	0.022	9.999	0.003	1.8072	0.0011
1037	43.567	0.022	9.994	0.003	1.8063	0.0011
1038	43.510	0.022	9.981	0.003	1.8040	0.0011
1039	44.416	0.023	10.189	0.003	1.8415	0.0011
1040	43.571	0.022	9.995	0.003	1.8065	0.0011
1041	43.612	0.022	10.005	0.003	1.8082	0.0011
1042	44.426	0.023	10.191	0.003	1.8419	0.0011
1043	44.360	0.023	10.176	0.003	1.8392	0.0011
1044	44.435	0.023	10.193	0.003	1.8423	0.0011
1045	43.585	0.022	9.998	0.003	1.8070	0.0011
1046	44.348	0.023	10.174	0.003	1.8387	0.0011
1047	43.543	0.022	9.989	0.003	1.8053	0.0011
1048	43.578	0.022	9.997	0.003	1.8068	0.0011
1049	43.576	0.022	9.996	0.003	1.8067	0.0011
1050	43.576	0.022	9.996	0.003	1.8067	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
1051	43.609	0.022	10.004	0.003	1.8080	0.0011
1052	44.424	0.023	10.191	0.003	1.8419	0.0011
1053	43.545	0.022	9.989	0.003	1.8054	0.0011
1054	44.447	0.023	10.196	0.003	1.8428	0.0011
1055	44.400	0.023	10.186	0.003	1.8409	0.0011
1056	43.566	0.022	9.994	0.003	1.8063	0.0011
1057	43.614	0.022	10.005	0.003	1.8083	0.0011
1058	43.578	0.022	9.997	0.003	1.8068	0.0011
1059	44.445	0.023	10.196	0.003	1.8427	0.0011
1060	43.543	0.022	9.989	0.003	1.8053	0.0011
1061	44.404	0.023	10.186	0.003	1.8410	0.0011
1062	44.357	0.023	10.176	0.003	1.8391	0.0011
1063	43.578	0.022	9.997	0.003	1.8068	0.0011
1064	43.597	0.022	10.001	0.003	1.8075	0.0011
1065	44.438	0.023	10.194	0.003	1.8424	0.0011
1066	43.553	0.022	9.991	0.003	1.8058	0.0011
1067	43.547	0.022	9.990	0.003	1.8055	0.0011
1068	43.545	0.022	9.989	0.003	1.8054	0.0011
1069	43.524	0.022	9.985	0.003	1.8045	0.0011
1070	43.623	0.022	10.007	0.003	1.8086	0.0011
1071	44.426	0.023	10.191	0.003	1.8419	0.0011
1072	43.553	0.022	9.991	0.003	1.8058	0.0011
1073	43.588	0.022	9.999	0.003	1.8072	0.0011
1074	43.543	0.022	9.989	0.003	1.8053	0.0011
1075	43.567	0.022	9.994	0.003	1.8063	0.0011
1076	43.604	0.022	10.003	0.003	1.8078	0.0011
1077	44.395	0.023	10.184	0.003	1.8406	0.0011
1078	44.437	0.023	10.194	0.003	1.8424	0.0011
1079	44.412	0.023	10.188	0.003	1.8414	0.0011
1080	44.388	0.023	10.183	0.003	1.8404	0.0011
1081	44.416	0.023	10.189	0.003	1.8415	0.0011
1082	44.419	0.023	10.190	0.003	1.8416	0.0011
1083	43.547	0.022	9.990	0.003	1.8055	0.0011
1084	44.404	0.023	10.186	0.003	1.8410	0.0011
1085	43.505	0.022	9.980	0.003	1.8037	0.0011
1086	44.395	0.023	10.184	0.003	1.8406	0.0011
1087	44.338	0.023	10.171	0.003	1.8383	0.0011
1088	44.443	0.023	10.195	0.003	1.8427	0.0011
1089	44.407	0.023	10.187	0.003	1.8411	0.0011
1090	43.571	0.022	9.995	0.003	1.8065	0.0011
1091	43.574	0.022	9.996	0.003	1.8066	0.0011
1092	44.430	0.023	10.192	0.003	1.8421	0.0011
1093	43.503	0.022	9.980	0.003	1.8037	0.0011
1094	43.630	0.022	10.009	0.003	1.8089	0.0011
1095	44.390	0.023	10.183	0.003	1.8404	0.0011
1096	44.395	0.023	10.184	0.003	1.8406	0.0011
1097	44.454	0.023	10.198	0.003	1.8431	0.0011
1098	43.566	0.022	9.994	0.003	1.8063	0.0011
1099	43.579	0.022	9.997	0.003	1.8068	0.0011
1100	43.481	0.022	9.975	0.003	1.8027	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
1101	44.480	0.023	10.204	0.003	1.8442	0.0011
1102	43.519	0.022	9.983	0.003	1.8043	0.0011
1103	43.604	0.022	10.003	0.003	1.8078	0.0011
1104	43.590	0.022	10.000	0.003	1.8073	0.0011
1105	44.372	0.023	10.179	0.003	1.8397	0.0011
1106	43.507	0.022	9.981	0.003	1.8038	0.0011
1107	43.578	0.022	9.997	0.003	1.8068	0.0011
1108	44.411	0.023	10.188	0.003	1.8413	0.0011
1109	43.545	0.022	9.989	0.003	1.8054	0.0011
1110	43.553	0.022	9.991	0.003	1.8058	0.0011
1111	43.626	0.022	10.008	0.003	1.8088	0.0011
1112	44.371	0.023	10.179	0.003	1.8396	0.0011
1113	44.433	0.023	10.193	0.003	1.8422	0.0011
1114	43.550	0.022	9.991	0.003	1.8056	0.0011
1115	44.388	0.023	10.183	0.003	1.8404	0.0011
1116	43.585	0.022	9.998	0.003	1.8070	0.0011
1117	44.376	0.023	10.180	0.003	1.8399	0.0011
1118	44.430	0.023	10.192	0.003	1.8421	0.0011
1119	43.531	0.022	9.986	0.003	1.8048	0.0011
1120	43.533	0.022	9.987	0.003	1.8049	0.0011
1121	44.379	0.023	10.181	0.003	1.8400	0.0011
1122	43.593	0.022	10.000	0.003	1.8074	0.0011
1123	44.423	0.023	10.191	0.003	1.8418	0.0011
1124	43.559	0.022	9.992	0.003	1.8060	0.0011
1125	43.547	0.022	9.990	0.003	1.8055	0.0011
1126	44.411	0.023	10.188	0.003	1.8413	0.0011
1127	44.402	0.023	10.186	0.003	1.8409	0.0011
1128	44.385	0.023	10.182	0.003	1.8402	0.0011
1129	43.555	0.022	9.992	0.003	1.8058	0.0011
1130	44.483	0.023	10.205	0.003	1.8443	0.0011
1131	44.412	0.023	10.188	0.003	1.8414	0.0011
1132	43.562	0.022	9.993	0.003	1.8061	0.0011
1133	44.371	0.023	10.179	0.003	1.8396	0.0011
1134	44.463	0.023	10.200	0.003	1.8434	0.0011
1135	44.359	0.023	10.176	0.003	1.8391	0.0011
1136	44.402	0.023	10.186	0.003	1.8409	0.0011
1137	44.437	0.023	10.194	0.003	1.8424	0.0011
1138	43.595	0.022	10.001	0.003	1.8075	0.0011
1139	44.372	0.023	10.179	0.003	1.8397	0.0011
1140	43.533	0.022	9.987	0.003	1.8049	0.0011
1141	44.412	0.023	10.188	0.003	1.8414	0.0011
1142	44.440	0.023	10.195	0.003	1.8425	0.0011
1143	44.416	0.023	10.189	0.003	1.8415	0.0011
1144	43.559	0.022	9.992	0.003	1.8060	0.0011
1145	44.409	0.023	10.188	0.003	1.8412	0.0011
1146	44.378	0.023	10.180	0.003	1.8399	0.0011
1147	43.592	0.022	10.000	0.003	1.8073	0.0011
1148	43.500	0.022	9.979	0.003	1.8035	0.0011
1149	43.630	0.022	10.009	0.003	1.8089	0.0011
1150	43.536	0.022	9.987	0.003	1.8050	0.0011

Vial No.	^{238}U		^{235}U		^{239}Pu	
	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]	Mass [1] [mg]	Uncertainty [2] [mg]
1151	43.654	0.022	10.014	0.003	1.8099	0.0011
1152	43.650	0.022	10.014	0.003	1.8098	0.0011

[1] The certified values are traceable to the values on the respective metal certificates (EC NRM 101, NBL CRM 116-A and CETAMA MP2). The reference date for the masses of ^{238}U, ^{235}U and ^{239}Pu is November 1, 2015.

[2] The certified uncertainty is the expanded uncertainty with a coverage factor $k = 2$ (with the exception for the mass of ^{239}Pu with a coverage factor of $k = 2.3$) corresponding to a level of confidence of about 95 % estimated in accordance with ISO/IEC Guide 98-3, Guide to the Expression of Uncertainty in Measurement (GUM:1995), ISO, 2008.

Annex 2: The certificate of EC NRM 101 uranium metal

Certified Nuclear Reference Material

Certificate of Analysis

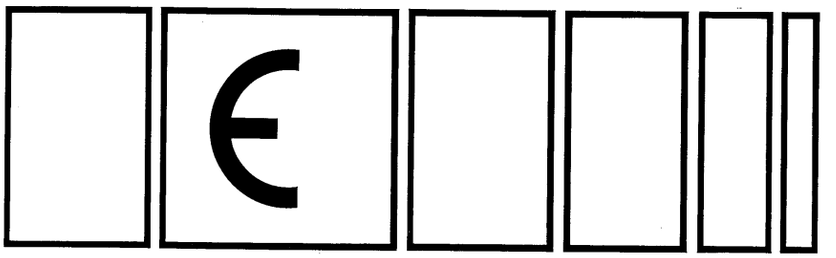
EC NUCLEAR REFERENCE MATERIAL NO. 101

MATERIAL : URANIUM METAL

URANIUM MASS FRACTION : (999.85 ± 0.05) g·kg^{-1}

The uncertainty has been calculated by multiplying the estimated overall standard deviation by a factor of two. This corresponds to a confidence level of about 95 percent.

Commission of the European Communities
Joint Research Centre
Geel Establishment (CBNM)



Annex 3: The certificate of NBL CRM 116-A uranium metal

New Brunswick Laboratory
U.S. Department of Energy

Certificate of Analysis
CRM 116-A
Uranium (enriched) Metal Assay and Isotopic Standard

Certified Property Values

Amount Content	Value	Expanded[1] Uncertainty	Isotope-Amount Ratio	Value	Expanded[1] Uncertainty
g U•g^{-1} metal	0.99945	0.00014	$n(^{233}U)/n(^{235}U)$	0.0000003863	0.0000000086
			$n(^{234}U)/n(^{235}U)$	0.0115836	0.0000097
Molar Mass	Value	Expanded[1] Uncertainty	$n(^{236}U)/n(^{235}U)$	0.0094713	0.0000077
g•mol^{-1}	235.18572	0.00011	$n(^{238}U)/n(^{235}U)$	0.051277	0.000041
Isotope-Amount Fraction (•100)	Value	Expanded[1] Uncertainty	Isotope Mass Fraction (•100)	Value	Expanded[1] Uncertainty
$n(^{233}U)/n(U)$	0.00003603	0.00000080	$m(^{233}U)/m(U)$	0.00003570	0.00000079
$n(^{234}U)/n(U)$	1.08023	0.00089	$m(^{234}U)/m(U)$	1.07497	0.00088
$n(^{235}U)/n(U)$	93.2547	0.0038	$m(^{235}U)/m(U)$	93.1985	0.0038
$n(^{236}U)/n(U)$	0.88324	0.00071	$m(^{236}U)/m(U)$	0.88647	0.00071
$n(^{238}U)/n(U)$	4.7818	0.0036	$m(^{238}U)/m(U)$	4.8401	0.0037

[1] Expanded uncertainties for certified property values have a coverage factor of approximately 2.0 with the exception of the amount content value which has a coverage factor of 2.4 and the ^{233}U values which have a coverage factor of 3.3 for isotope amount ratio, isotope-amount fraction, and isotope mass fraction.

Notes:

Certified Reference Material 116-A (CRM 116-A) is a uranium amount content and isotope-amount ratio standard intended for use in calibration of and/or quality control for uranium analysis methods. Each unit of CRM 116-A consists of a metal piece with a mass of approximately 1.1 grams. This CRM is not characterized for total quantity of material which may be somewhat greater or less than the nominal mass (between 1.0 g and 1.2 g).

CRM 116-A is a radioactive material and should be handled and stored under proper radiologically-controlled conditions at all times.

October 31, 2013
Steven Bakhtiar
Laboratory Director

New Brunswick Laboratory
Argonne, Illinois
www.science.energy.gov/nbl

CRM 116-A units do not have an expiration date. To maintain the integrity of an unused unit, it should remain in the original packaging and should be stored in a dry, temperature controlled location.

Measurements for uranium amount content and isotope-amount ratios were performed on metal samples with a mass of 1.1 gram or greater. The homogeneity of uranium amount content or isotopic composition has not been assessed for metal pieces smaller than 1.1 gram. Prior to use, surface oxide must be removed to ensure accurate uranium amount content values. A suggested procedure is provided below.

Suggested Preparation Procedure for Achieving Accurate Mass and Amount Content Values

1. Cover the uranium metal sample in 8 $mol \cdot L^{-1}$ nitric acid for 10-20 minutes to remove all visible surface oxides.
2. To minimize oxidation of the sample and ensure an accurate determination of uranium metal mass, the following steps should be performed immediately following Step 1.
   2.1 Thoroughly rinse the metal piece with distilled, deionized water.
   2.2 Remove excess water by thoroughly rinsing the metal piece with pure acetone.
   2.3 Allow the acetone to evaporate (30 – 60 seconds is typically sufficient).
   2.4 Perform a weighing of sufficient accuracy and precision for user's need.

Description:

The CRM 116-A metal pieces are machined metal cylinders. The stock material for the CRM was obtained from a single casting of a HEU right-annular cylinder of metal. Several wedges of material were cut from the annular cylinder and machined into rods which were stamped into narrow-diameter rods. The rods were then machined to shape and cut into the individual 1.1-gram metal cylinders that comprise each CRM 116-A unit.

Uranium amount content for CRM 116-A was determined by the NBL High Precision Titrimetric method using CRM 99 Potassium Dichromate Oxidimetric Standard as the titrant. The CRM 112-A Uranium Metal Assay and Isotopic Standard was used as a control to verify performance of the measurement system. Traceability of the measurements is primarily established by direct determination of uranium amount content based on the titration of uranium using CRM 99 Potassium Dichromate Oxidimetric Standard. CRM 99 was calibrated against CRM 112-A which, in turn, was originally provided by the National Bureau of Standards (now known as the National Institute of Standards and Technology) as SRM 960.

A detailed thermal ionization mass spectrometry measurement campaign was performed on CRM 116-A to determine uranium isotope-amount ratios and uncertainties. Mass discrimination calibrations were performed on a sample turret basis using multiple measurements of NBL Uranium Isotopic Standards U900 and U930-D. Analyses of CRM U970 Uranium Isotopic Standard were performed to verify that mass spectrometric measurements were in control. Traceability of the isotope-amount ratio measurements for CRM 116-A was established by calibration of the mass spectrometers using combined measurements of CRMs U900 and U930-D Uranium Isotopic Standards. CRM 900 was originally provided by the National Bureau of Standards (now known as the National Institute of Standards and Technology) as SRM U900. U930-D is directly traceable to National Bureau of Standards SRM U930 Uranium Isotopic Standard.

Measurement Uncertainty:

Reported numerical uncertainties for values are expressed as expanded uncertainties ($U = k \cdot u_c$) at the 95% level of confidence, where the expanded uncertainty (U) is the product of the combined standard uncertainty (u_c) and a coverage factor (k). The last figure in reported values and uncertainties is provided for information purposes and is not intended to convey a significant degree of reliability. The isotope-amount and weight fraction values and uncertainties are provided primarily for information purposes. To assure proper uncertainty propagation, it is recommended that isotope-amount ratios and associated uncertainties be used for calculations incorporating CRM 116-A values.

Uncertainties were determined according to the protocols outlined in JCGM 100:2008 *Guide to the Expression of Uncertainty in Measurement*. The combined standard uncertainties for attribute values consist of Type A and Type B components. The Type A uncertainty components for amount content is derived from the standard deviation of high precision titrations performed on 1.1 g U metal samples and the standard uncertainty for the primary analytical amount content measurements, which utilized 3-g U metal samples. The Type B component is the combined standard uncertainty of the CRM 99 oxidimetric standard. The Type A components for isotope-amount ratios are derived from standard deviations associated with isotopic ratio measurements of the samples and the $n(^{238}U)/n(^{235}U)$ ratio of NBL CRMs U900 and U930-D. Type B components are based on the combined standard uncertainties for the $n(^{238}U)/n(^{235}U)$ ratios of CRMs U900 and U930-D and components to account for additional sources of uncertainty associated with background corrections and analytical biases. Isotope mass fractions incorporate an additional Type B component associated with the uncertainty of the atomic mass for the U isotopes. The coverage factor (k) for each expanded uncertainty is based on the effective degrees of freedom for that quantity and is the Student's t-factor necessary to provide a 95% level of confidence ($k \approx 2.0$ for the values cited in this certificate except for the amount content value with $k = 2.4$ and the ^{233}U isotope amount ratio, amount fraction, and mass fraction which have coverage factors of $k = 3.3$). A more detailed explanation of measurement uncertainty can be obtained upon request from NBL.

References:

Bureau International des Poids et Measures (BIPM), Evaluation of Measurement Data - Guide to the Expression of Uncertainty in Measurement, JCGM 100: 2008.

Annex 4: The certificate of CETAMA MP2 plutonium metal

CETAMA

COMMISSARIAT A L'ENERGIE ATOMIQUE

COMMISSION D'ETABLISSEMENT DES METHODES D'ANALYSE

cea

REFERENCE MATERIAL CERTIFICATE

PLUTONIUM METAL
"MP2"

Sample n° Xxxx Mass : 0.xxxxxx ± 0.000012 g

(For X and x values see list page 4)

The reference material to which this certificate relates is intended for the calibration of chemical composition measurement. The overall chemical content of plutonium is certified. The confidence interval associated with the certified value for a single sample, takes into account uncertainties associated to with analysis and heteregenity of metal. This content, expressed as a percentage of mass, was the following on 12 march 2001 for a single sample with a probability level of 0.95.

99.90 ± 0.04 %

THE TRUE MASS OF THE SAMPLE A ± **12** µg, RELATED TO A VACUUM, IS THAT INDICATED IN THIS CERTIFICATE AND ON THE AMPOULE.

The possibility of surface oxidation makes it impossible to envisage weighing at the time of use

Isotopique composition is certified on 12 march 2001 : see certificate IRMM page3

The preparation, analysis and certification of the plutonium to which this certificate relates was carried out by different units of the CEA group under the supervision of the Committee for Establishing Analysis Methods (CETAMA).

CETAMA CRM manager

CETAMA
CEA VALRHO Marcoule
30207 BAGNOLS SUR CEZE CEDEX
Téléphone 04.66.79.69.88 - Télécopie 04.66.79.69.89

ISO 9001 BUREAU VERITAS Certification

Version : 10.2007

On 12/03/2001, the metal contained around:

- by weight, 489 $mg.kg^{-1}$ of uranium,
- by weight, 438 $mg.kg^{-1}$ of américium..

UTILISATION

The sample, which consists of a piece of metal, is supplied in a double glass ampoule filled with pure nitrogen at a pressure of around 0.1 Pascal.

The ampoule must be opened with care inside a glove box. All the sample must be transferred to the dissolver.

Cover with 0.1 $mol.l^{-1}$ hydrochloric acid. The ampoule must be thoroughly washed with the same acid to recover any particles of metal which may have become separated. In 2 ml fractions, add the necessary quantity of 12 $mol.l^{-1}$ hydrochloric acid of guaranteed purity to obtain a 4 $mol.l^{-1}$ hydrochloric acid solution. Allow dissolving to proceed without heating for 10 to 15 minutes, then heat to boiling point. If there are still particles of plutonium at the bottom of the dissolver after heating for two hours, add 2 ml of 12 $mol.l^{-1}$ hydrochloric acid and 2 drops of 1 $mol.l^{-1}$ hydrofluoric acid and continue heating for another two hours. Repeat the operation if necessary until the material is totally dissolved.
If plutonium fluoride precipitates out, add a few drops of aluminium nitrate (approximately one $mol.l^{-1}$)..
Allow to cool and adjust to the required volume.

ADDITIONAL INFORMATION

The certified plutonium content has been deduced from analysis of impurities carried out by five laboratories and checked by chemical assay of the plutonium in two different laboratories using three different methods of analysis.
Spark Source Mass Spectrometry has given a full analysis of the impurities and, where concentration levels allowed, inductively-coupled plasma atomic emission spectrometry has been used to establish the concentrations of some of them.
The uranium was determined by laser spectrofluorimetry and the americium by gamma spectrometry.Carbon was determined by coulometry, after transformation into gaseous form by combustion in oxygen.
The gases were analysed by chromatography in the aqueous phase:
- for nitrogen and oxygen after extraction by high temperature stream under an inert gas,
- for hydrogen after diffusion in a vacuum.

CETAMA
CEA VALRHO Marcoule
30207 BAGNOLS SUR CEZE CEDEX
Téléphone 04.66.79.69.88 - Télécopie 04.66.79.69.89

IRMM

Institute for Reference Materials and Measurements

CERTIFICATE OF ISOTOPIC COMPOSITION

Geel, 30 May 2001

1. Applicant: Mr G. Lamarque
   Président de la Cetama

2. Sample Identification: MP2 (Pu metal)

3. Isotopic composition:

isotope amount ratio(s)	
$n(^{238}Pu)/n(^{239}Pu)$	0.000 033 15(41)
$n(^{240}Pu)/n(^{239}Pu)$	0.022 437 4(99)
$n(^{241}Pu)/n(^{239}Pu)$	0.000 298 0(17)
$n(^{242}Pu)/n(^{239}Pu)$	0.000 070 87(71)

amount fraction (·100)		mass fraction (·100)	
$n(^{238}Pu)/n(Pu)$	0.003 241(40)	$m(^{238}Pu)/m(Pu)$	0.003 227(40)
$n(^{239}Pu)/n(Pu)$	97.767 05(98)	$m(^{239}Pu)/m(Pu)$	97.757 76(98)
$n(^{240}Pu)/n(Pu)$	2.193 64(94)	$m(^{240}Pu)/m(Pu)$	2.202 62(95)
$n(^{241}Pu)/n(Pu)$	0.029 14(17)	$m(^{241}Pu)/m(Pu)$	0.029 38(17)
$n(^{242}Pu)/n(Pu)$	0.006 929(69)	$m(^{242}Pu)/m(Pu)$	0.007 015(70)

molar mass: 239.074 888(11) $g \cdot mol^{-1}$

4. Reference number: IMN 10031

5. Remarks:

The above values are valid for 12 March 2001. All uncertainties indicated are expanded uncertainties $U = k \cdot u_c$ where u_c is the combined standard uncertainty calculated according to the ISO/BIPM guide. The uncertainties are given in parentheses and include a coverage factor k=2. They apply to the last two digits of the value. The values certified are traceable to the SI.
The primary certified values are the isotope amount ratios; other values are derived from them. Reproducing the derived values may result in differences due to rounding errors.
Mass spectrometric measurements were performed by A Verbruggen and F Kehoe by TIMS on samples chemically prepared by F Kehoe. A Verbruggen was responsible for the preparation and issuance of the certificate.

A Verbruggen
Isotope Measurements Unit

Copy: R Wellum
F Kehoe

B-2440 GEEL (Belgium)
Tel. +32-14-571 608 - Fax +32-14-571 883

European Commission - JRC

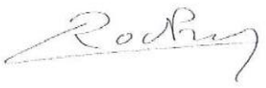
30207 BAGNOLS SUR CEZE CEDEX
Téléphone 04.66.79.69.88 - Télécopie 04.66.79.69.89

Packaging list for IRMM

The numbers of the ingots and the associated masses are as follows:

Ingot number	Mass (g)
A934	0.587859
A949	0.430987
A952	0.567216
A968	0.434526
A975	0.510770
C321	0.640299
C569	0.592943
C581	0.632827
A123	0.414082
A174	0.602206
A307	0.434852
A314	0.561821
A345	0.514834
A451	0.436194
A518	0.624022
A662	0.469822
A035	0.479086
A453	0.598728
A455	0.563210

CETAMA CRM manager



CETAMA
CEA VALRHO Marcoule
30207 BAGNOLS SUR CEZE CEDEX
Téléphone 04.66.79.69.88 - Télécopie 04.66.79.69.89

Annex 5: The certificate of isotopic abundances of CETAMA MP2

EUROPEAN COMMISSION
DIRECTORATE GENERAL JRC
JOINT RESEARCH CENTRE
IRMM
Institute for Reference Materials and Measurements

CERTIFICATE of a reference measurement

IM/MeaC/07/116

11 April 2007

SUBJECT : Recertification of CEA CETAMA MP2

1. Applicant: A. Verbruggen

2. Sample Identification:
   - CEA/CETAMA/MP2
   - Chemical form: Pu metal provided by CEA/CETAMA

3. Measurands:
   - Isotopic composition

isotope amount ratio(s)	
$n(^{238}Pu)/\ n(^{239}Pu)$	0.000 030 83(29)
$n(^{240}Pu)/\ n(^{239}Pu)$	0.022 432 4(51)
$n(^{241}Pu)/\ n(^{239}Pu)$	0.000 237 8(31)
$n(^{242}Pu)/\ n(^{239}Pu)$	0.000 075 70(78)

amount fraction (·100)		mass fraction (·100)	
$n(^{238}Pu)/n(Pu)$	0.003 015(29)	$m(^{238}Pu)/m(Pu)$	0.003 002(28)
$n(^{239}Pu)/n(Pu)$	97.773 05(58)	$m(^{239}Pu)/m(Pu)$	97.763 80(59)
$n(^{240}Pu)/n(Pu)$	2.193 28(49)	$m(^{240}Pu)/m(Pu)$	2.202 27(49)
$n(^{241}Pu)/n(Pu)$	0.023 25(30)	$m(^{241}Pu)/m(Pu)$	0.023 44(31)
$n(^{242}Pu)/n(Pu)$	0.007 402(76)	$m(^{242}Pu)/m(Pu)$	0.007 494(77)

molar mass: 239.074 790 8(91) $g \cdot mol^{-1}$

4. Date of sample receipt : n.a.
   Date of completion of measurement : 7 November 2006

5. All uncertainties indicated are expanded uncertainties $U = k \cdot u_c$ where u_c is the combined standard uncertainty estimated following the ISO/BIPM guide[1]. They are given in parentheses and include a coverage factor k=2. They apply to the last two digits of the value. The values certified are traceable to the SI. The primary certified values are the isotope amount ratio ; other values are derived from them. Reproducing the derived values may result in difference due to rounding errors.

[1] International Organisation for Standardisation, Guide to the expression of Uncertainty in Measurement, ©ISO, ISBN 92-67-10188-9, Geneva, Switserland, 1993

Uncertainty budget :

Quantity	Value	Standard Uncertainty	Index
Atomic mass ^{239}Pu	239.05215760 g/mol	$5.1 \cdot 10^{-6}$ g/mol	59.6 %
Measurement ratio 240/239	0.02243535 mol/mol	$3.81 \cdot 10^{-6}$ mol/mol	14.9 %
Measurement ratio 241/239	$240 \cdot 10^{-6}$ mol/mol	$450 \cdot 10^{-9}$ mol/mol	0.9 %
Measurement ratio 242/239	$75 \cdot 10^{-6}$ mol/mol	$175 \cdot 10^{-9}$ mol/mol	0.4 %
variability$_{241/239}$	0.0 mol/mol	$2.65 \cdot 10^{-6}$ mol/mol	21.0 %
variability$_{242/239}$	0.0 mol/mol	$650 \cdot 10^{-9}$ mol/mol	3.0 %
M_{Pu}	239.07478500 g/mol	$6.46 \cdot 10^{-6}$ g/mol	

6. The traceability to SI is established through standards from IRMM-290.

7. Analytical measurement procedure
   - Mass spectrometric measurments were performed by H Kühn an F Kehoe for the $[n(^{238}Pu)/n(^{239}Pu)]$, $[n(^{240}Pu)/n(^{239}Pu)]$, $[n(^{241}Pu)/n(^{239}Pu)]$ and $[n(^{242}Pu)/n(^{239}Pu)]$ using the MAT262 TIMS, sample solutions were prepared for TIMS analysis by F Kehoe. A. Verbruggen was responsible for preparation and issuance of the certificate.
   - The atomic masses, used in the calculation are from G. Audi and A.H. Wapstra.[2]
   - Reference numbers of the measurement data: measurements number T26629, T26A03, T26B07, logged in S:\D04-IM\Secure Data\Project Data\MP2 (based on 081a and LSD1027i)\MP2 IA Summary MAT262 measurements.
   - Full details of the preparation and the certification procedure can be found in certification report EUR*****.

8. These samples will be stored for a minimum period of six months from the date of this certificate

André Verbruggen
Group leader Nuclear Chemistry

Stephan Richter
Group leader Nuclear Mass Spectrometry

Copies
P Taylor, IM unit head
Y Aregbe, Action leader Nuclear Safeguards
F Kehoe
H Kühn

[2] G. Audi and A.H. Wapstra, The 2003 atomic mass evaluation, Nucl Phys A729 (2003) 337-676

Annex 6: The certificate of isotopic composition of EC NRM 101

European Commission
JOINT
RESEARCH
CENTRE

Institute for Reference Materials and Measurements
Steenweg op Retie,2440 Geel,Belgium
Tel.(014)571.211-Telex 33589 EURAT B
Telefax 014/58.42.73

CERTIFICATE OF ISOTOPIC COMPOSITION
****

1. Applicant : Dr.K.Mayer
Stable Isotope Measurements
IRMM

2. Sample identification : EC 101

3. Results :

	Amount Ratio(s)	Mass Ratio(s)	Uncertainty (computed on a 2s basis for each element)
n(234U)/n(238U)	0.00005548		+/- 0.00000022
n(235U)/n(238U)	0.0072593		+/- 0.0000036
n(236U)/n(238U)	0.000000151		+/- 0.000000040

4. Reference number : SMS 7315

5. Remarks : This sample will be stored for a minimum period of six months from the date of this certificate.

Request received at laboratory : 1995.06.23
Sample received at laboratory : 1995.06.23
Measurement achieved : 1995.06.23
Telephone or telex communication :

Mass spectrometric measurements were performed by W.De Bolle (n(235U)/n(238U) ratio by UF6) and A.Alonso (THMS) on samples chemically prepared by A.Alonso.

The values certified are traceable to the SI system and its unit for amount of substance: the mole.

c. P.De Bievre / A.Alonso

W.DE BOLLE
Stable Isotope Measurements

Annex 7: The certificate of IRMM-046b

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

Institute for Reference Materials and Measurements (Geel)

CERTIFIED REFERENCE MATERIAL
IRMM – 046b

CERTIFICATE OF ANALYSIS

Uranium and Plutonium in nitric acid solution

	Isotope amount content	
	Certified value [1] [µmol/g]	Uncertainty [2] [µmol/g]
^{242}Pu	0.46504	0.00018
^{233}U	4.1154	0.0009
	Isotope amount ratio	
	Certified value [1] [mol/mol]	Uncertainty [2] [mol/mol]
$n(^{234}U)/n(^{233}U)$	0.009396	0.000012
$n(^{235}U)/n(^{233}U)$	0.002252	0.000006
$n(^{236}U)/n(^{233}U)$	0.000280	0.000004
$n(^{238}U)/n(^{233}U)$	0.008186	0.000011
$n(^{238}Pu)/n(^{242}Pu)$	0.005332	0.000020
$n(^{239}Pu)/n(^{242}Pu)$	0.002212	0.000016
$n(^{240}Pu)/n(^{242}Pu)$	0.04607	0.00007
$n(^{241}Pu)/n(^{242}Pu)$	0.003000	0.000009
$n(^{244}Pu)/n(^{242}Pu)$	0.00024	0.00004

[1] The certified values are traceable to the International System of units (SI) via IRMM-1027m. The reference date for the certified values is June 1, 2010.
[2] The uncertainty is the expanded uncertainty with a coverage factor $k = 2$ corresponding to a level of confidence of about 95 % estimated in accordance with ISO/IEC Guide 98-3, Guide to the Expression of Uncertainty in Measurement (GUM:1995), ISO, 2008.

The certificate is valid for 3 years; the validity may be extended after further tests on the stability of the material are carried out.

Geel, June 2010,

Last revision February 2016

Signed: 16/02/2016

Prof. Dr. Hendrik Emons
European Commission
Joint Research Centre
Institute for Reference Materials and Measurements
Retieseweg 111
B-2440 Geel, Belgium

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Additional Material Information

	Isotopic mass fraction	
	Value [1] [g/g]	Uncertainty [2] [g/g]
$m(^{233}U)/m(U)$ [3]	0.980053	0.000017
$m(^{234}U)/m(U)$ [3]	0.009248	0.000012
$m(^{235}U)/m(U)$ [3]	0.002226	0.000006
$m(^{236}U)/m(U)$ [3]	0.000278	0.000004
$m(^{238}U)/m(U)$ [3]	0.008195	0.000011
$m(^{238}Pu)/m(Pu)$ [3]	0.004964	0.000018
$m(^{239}Pu)/m(Pu)$ [3]	0.002068	0.000015
$m(^{240}Pu)/m(Pu)$ [3]	0.04325	0.00006
$m(^{241}Pu)/m(Pu)$ [3]	0.002828	0.000009
$m(^{242}Pu)/m(Pu)$ [3]	0.94667	0.00007
$m(^{244}Pu)/m(Pu)$ [3]	0.000226	0.000030
	Amount content	
	Value [1] [µmol/g]	Uncertainty [2] [µmol/g]
Pu	0.49147	0.00019
U	4.1982	0.0009
	Mass fraction	
	Value [1] [mg/g]	Uncertainty [2] [mg/g]
Pu	0.11891	0.00005
U	0.97857	0.00020
	Molar mass	
	Value [1] [g/mol]	Uncertainty [2] [g/mol]
Pu	241.94244	0.00015
U	233.09432	0.00006

[1] The information values are derived from the certified values. The reference date for the derived values is June 1, 2010.
[2] The uncertainty is the expanded uncertainty with a coverage factor $k = 2$ corresponding to a level of confidence of about 95 % estimated in accordance with ISO/IEC Guide 98-3, Guide to the Expression of Uncertainty in Measurement (GUM:1995), ISO, 2008.
[3] Isotopic mass fraction is expressed as $^{xxx}U/^{tot}U$ and $^{xxx}Pu/^{tot}Pu$.

DESCRIPTION OF THE MATERIAL

The IRMM-046b is a mixed uranium-plutonium spike Certified Reference Material (CRM) supplied with an isotope amount content of ^{233}U and ^{242}Pu and isotope amount ratios as certified above. A unit of IRMM-046b consists of a flame-sealed glass ampoule containing about 10 mg uranium and 1 mg plutonium in 10 mL of nitric acid solution. The concentration of nitric acid is about 5 mol-L^{-1}.

ANALYTICAL METHODS USED FOR CERTIFICATION

The certified values were established by isotope dilution mass spectrometry (IDMS) on randomly selected units of IRMM-046b. The isotope ratio measurements were performed on a Triton TIMS (Thermo Fisher Scientific) using the total evaporation method. Pu standard IRMM-290/A3 and U standard IRMM-074/10 were used to correct for the mass fractionation effects during isotopic measurement.

SAFETY INFORMATION

The IRMM-046b contains radioactive material. The ampoules should be handled with great care and by experienced personnel in a laboratory suitably equipped for the safe handling of radioactive materials.

INSTRUCTIONS FOR USE AND INTENDED USE

This spike Certified Reference Material (CRM) is used as a calibrant to determine the plutonium and uranium amount content by isotope dilution mass spectrometry (IDMS).

STORAGE

The vials should be stored at + 18 °C ± 5 °C in an upright position.
However, the European Commission cannot be held responsible for changes that happen during storage of the material at the customer's premises, especially of opened samples.

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Annex 8: Results of the IDMS confirmation measurements (4 blends, 4 replicates) for ^{235}U, ^{238}U and ^{239}Pu amount content in the mother solution of IRMM-1027r

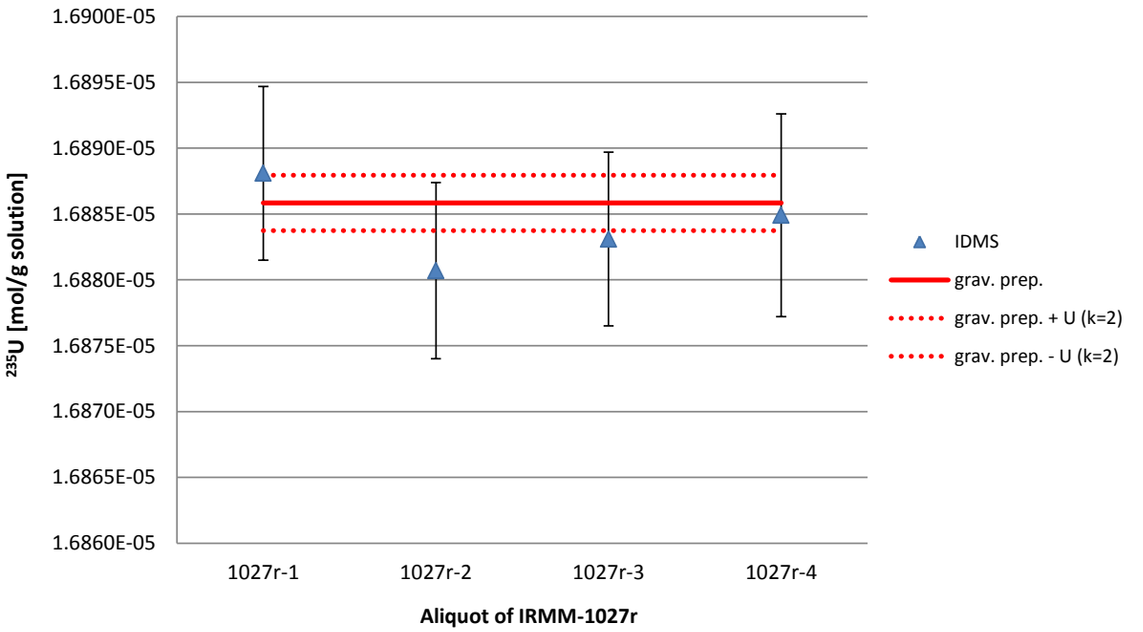

Fig 3. The amount content of ^{235}U in the solution of IRMM-1027r prepared by gravimetric mixing compared with the measured values by IDMS (with expanded uncertainties, coverage factor k = 2).

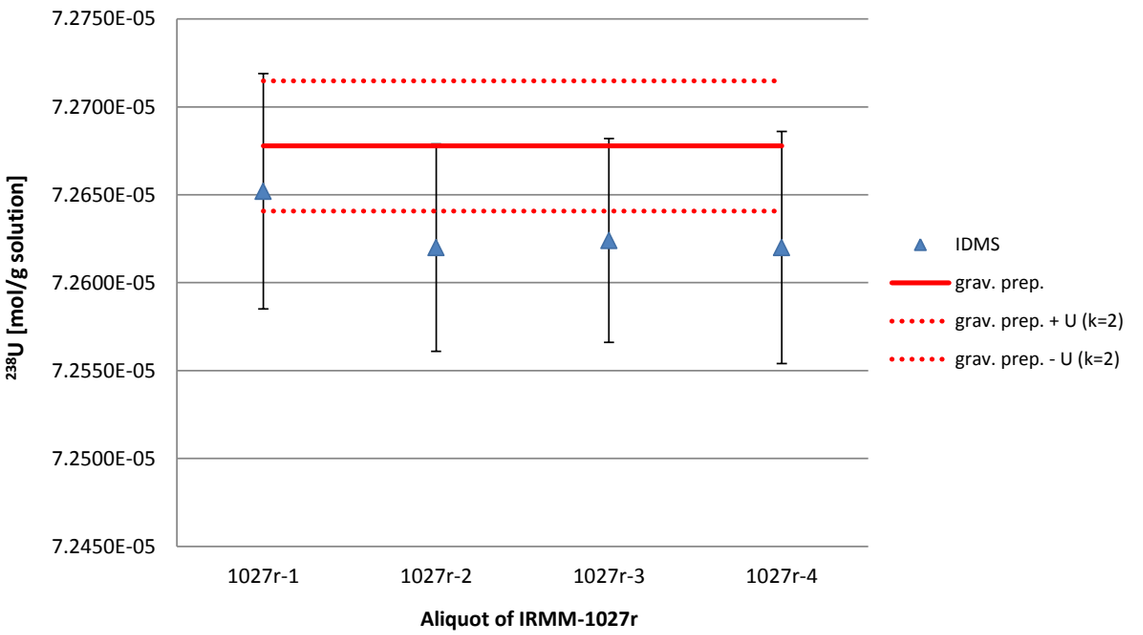

Fig 4. The amount content of ^{238}U in the solution of IRMM-1027r prepared by gravimetric mixing compared with the measured values by IDMS (with expanded uncertainties, coverage factor k = 2).

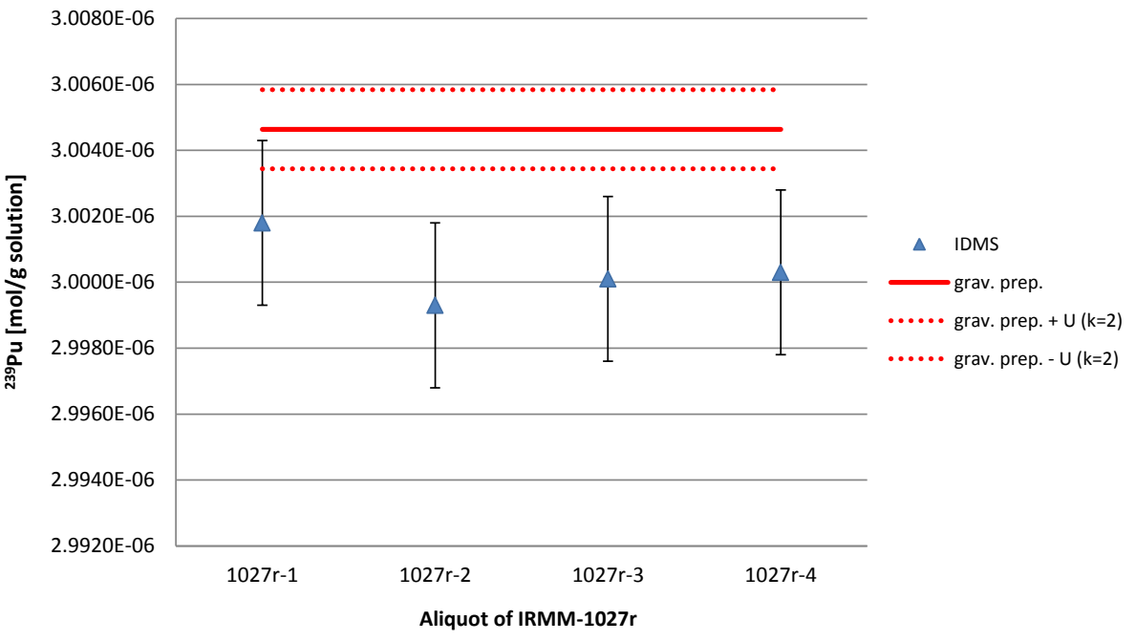

Fig 5. The amount content of ^{239}Pu in the solution of IRMM-1027r prepared by gravimetric mixing compared with the measured values by IDMS (with expanded uncertainties, coverage factor k = 2).

Annex 9: Results of the TIMS confirmation measurements (4 aliquots, 4 replicates) for the uranium and plutonium isotope amount ratios in the mother solution of IRMM-1027r

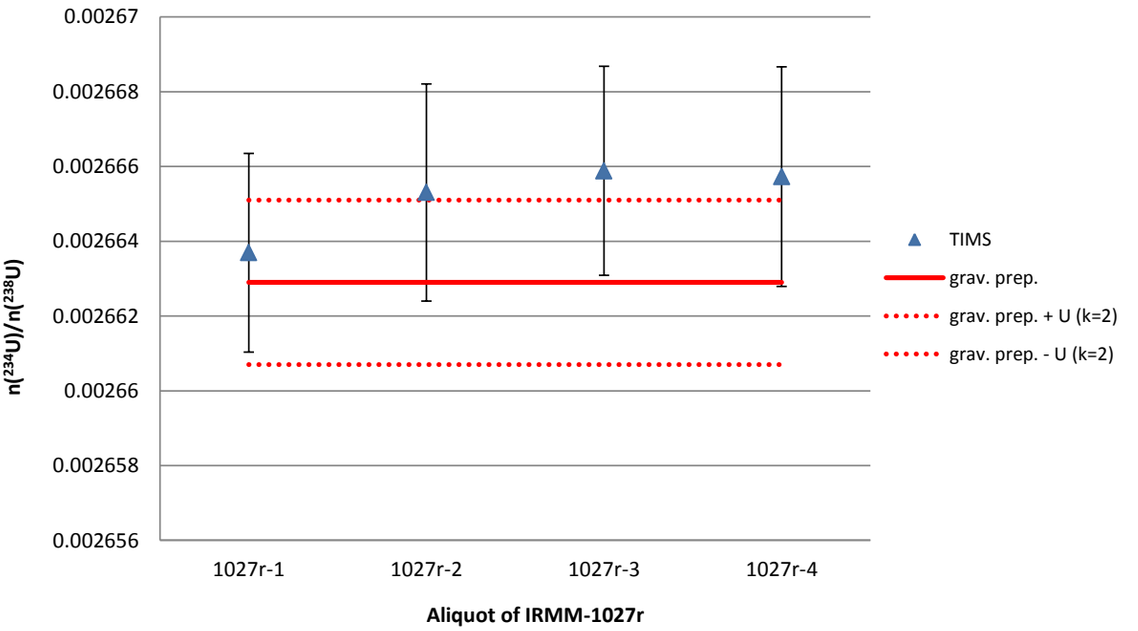

Fig 6. The $n(^{234}U)/n(^{238}U)$ amount ratio in the solution of IRMM-1027r prepared by gravimetric mixing compared with the measured values by TIMS (with expanded uncertainties, coverage factor $k = 2$).

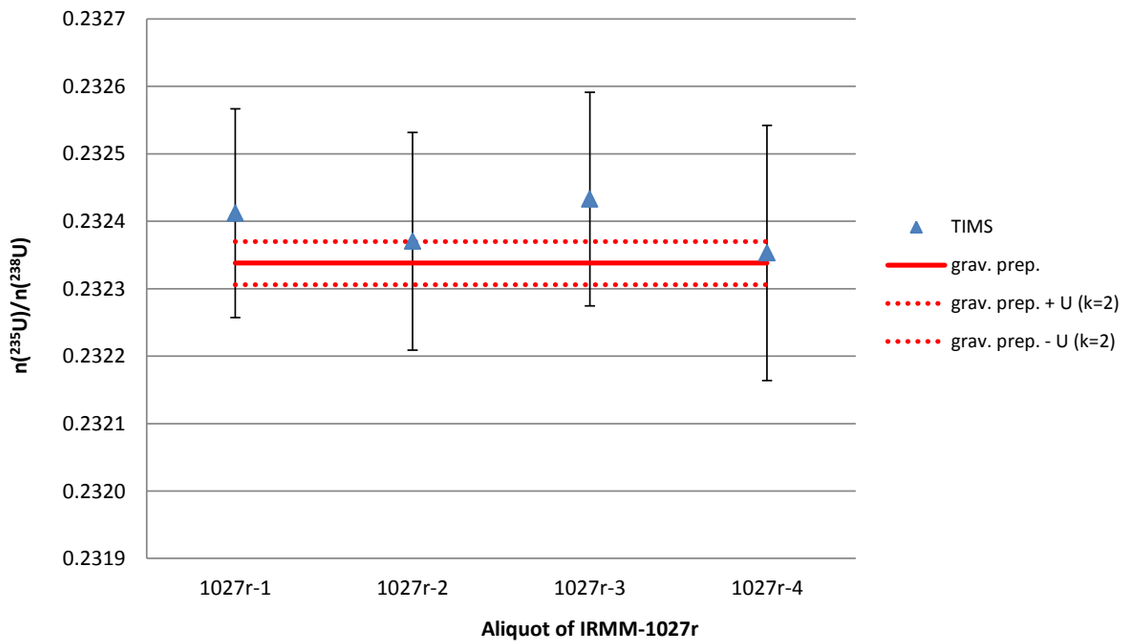

Fig 7. The $n(^{235}U)/n(^{238}U)$ amount ratio in the solution of IRMM-1027r prepared by gravimetric mixing compared with the measured values by TIMS (with expanded uncertainties, coverage factor $k = 2$).

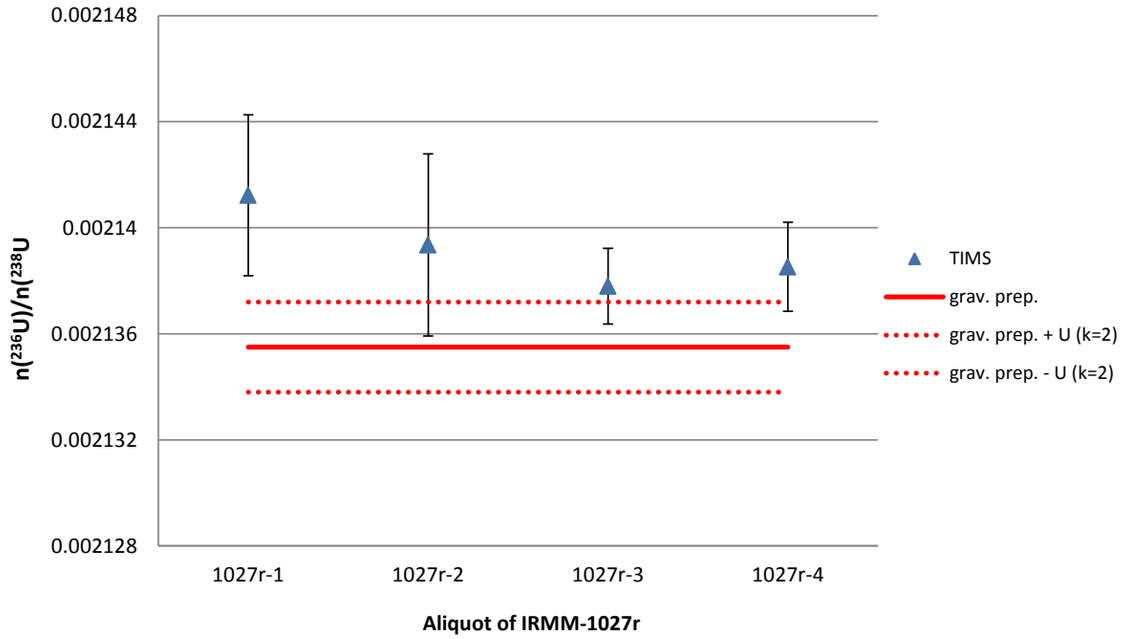

Fig 8. The $n(^{236}U)/n(^{238}U)$ amount ratio in the solution of IRMM-1027r prepared by gravimetric mixing compared with the measured values by TIMS (with expanded uncertainties, coverage factor $k = 2$).

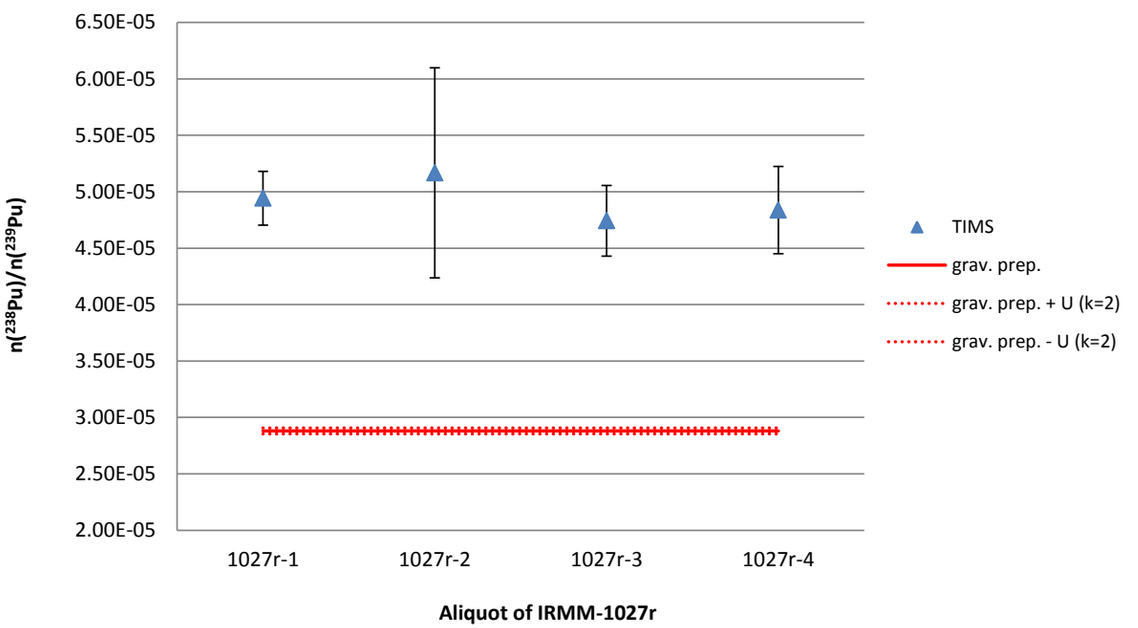

Fig 9. The $n(^{238}Pu)/n(^{239}Pu)$ amount ratio in the solution of IRMM-1027r prepared by gravimetric mixing compared with the measured values by TIMS (with expanded uncertainties, coverage factor $k = 2$).

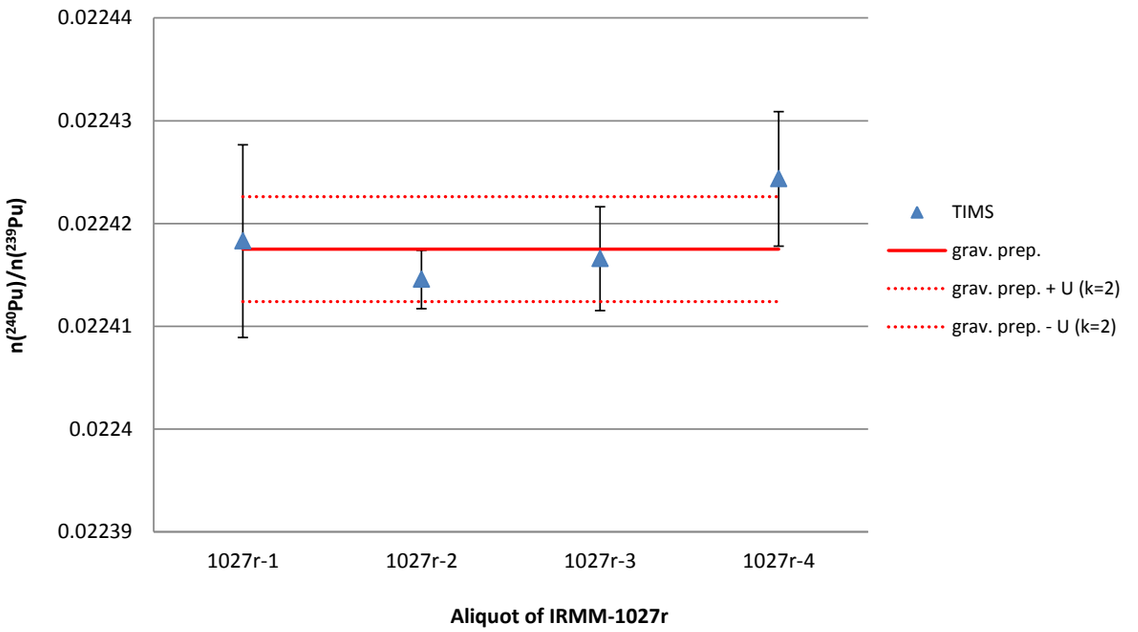

Fig 10. The $n(^{240}Pu)/n(^{239}Pu)$ amount ratio in the solution of IRMM-1027r prepared by gravimetric mixing compared with the measured values by TIMS (with expanded uncertainties, coverage factor $k = 2$).

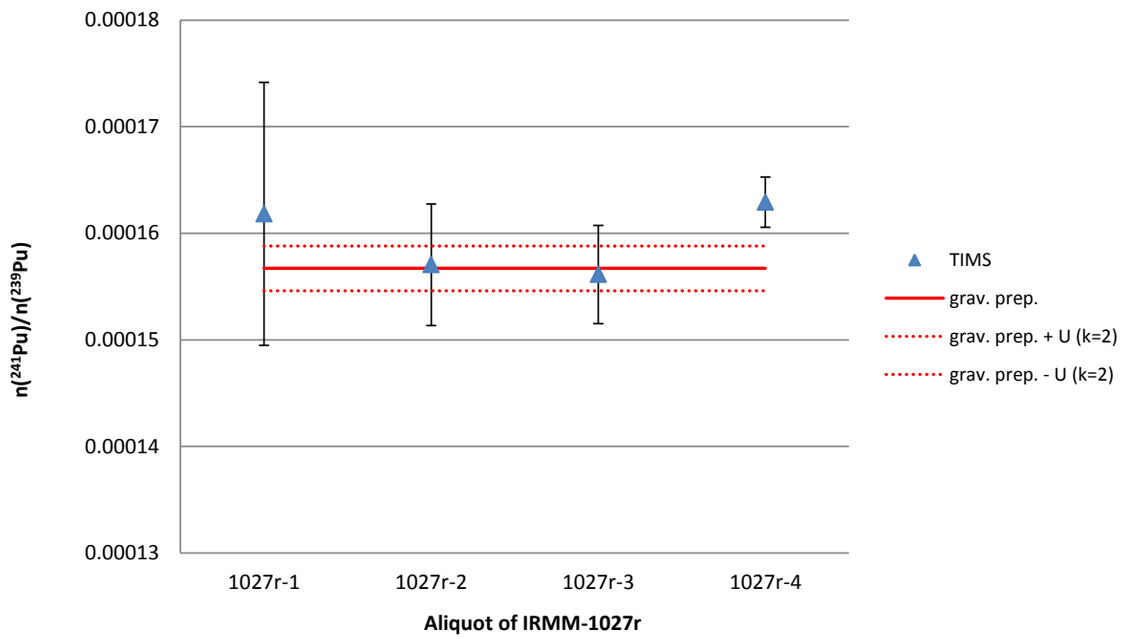

Fig 11. The $n(^{241}Pu)/n(^{239}Pu)$ amount ratio in the solution of IRMM-1027r prepared by gravimetric mixing compared with the measured values by TIMS (with expanded uncertainties, coverage factor $k = 2$).

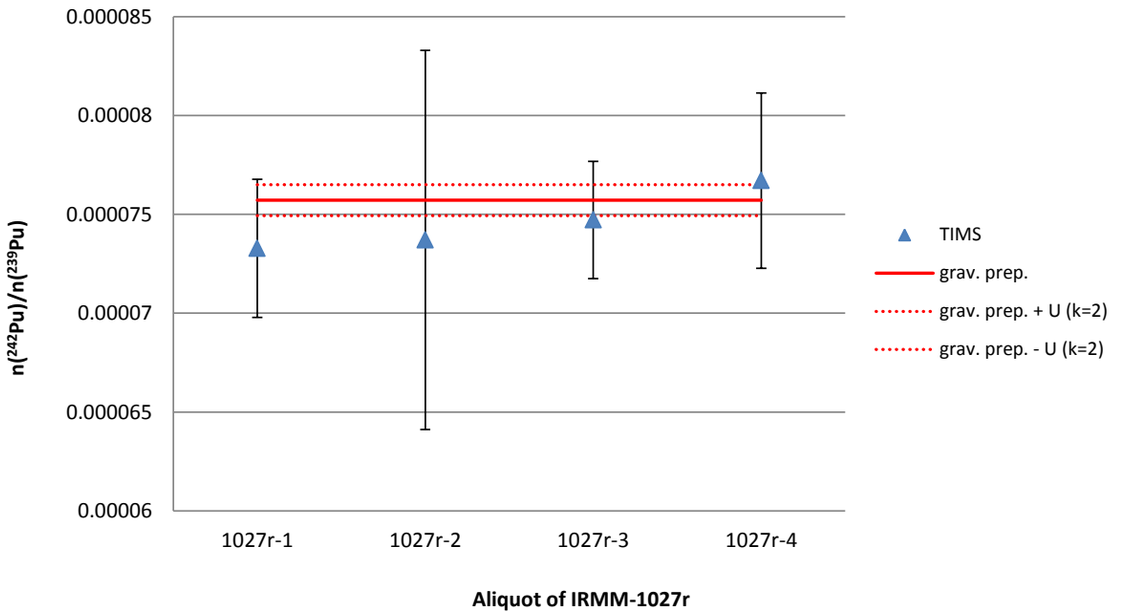

Fig 12. The $n(^{242}Pu)/n(^{239}Pu)$ amount ratio in the solution of IRMM-1027r prepared by gravimetric mixing compared with the measured values by TIMS (with expanded uncertainties, coverage factor $k = 2$).

Annex 10: Results of the homogeneity assessment (single value, mean and standard deviation) of the ^{235}U, ^{238}U and ^{239}Pu amount contents in the selected vials of IRMM-1027r

Unit	^{235}U [µmol/g]			
	Rep.1	Rep.2	Rep.3	Mean ± s
80	16.870	16.884	16.879	16.878 ± 0.007
268	16.882	16.881	16.886	16.883 ± 0.003
523	16.886	16.886	16.878	16.884 ± 0.005
179	16.873	16.880	16.871	16.875 ± 0.005
429	16.886	16.883	16.885	16.885 ± 0.002
610	16.891	16.902	16.886	16.893 ± 0.008
894	16.889	16.891	16.892	16.891 ± 0.002
1085	16.883	16.886	16.896	16.888 ± 0.007
756	16.891	16.886	16.900	16.892 ± 0.007
971	16.889	16.889	16.885	16.887 ± 0.002

Unit	^{238}U [µmol/g]			
	Rep.1	Rep.2	Rep.3	Mean ± s
80	72.526	72.682	72.619	72.609 ± 0.079
268	72.605	72.597	72.640	72.614 ± 0.023
523	72.646	72.647	72.550	72.614 ± 0.055
179	72.551	72.626	72.537	72.571 ± 0.048
429	72.655	72.625	72.644	72.642 ± 0.015
610	72.715	72.734	72.653	72.700 ± 0.042
894	72.668	72.668	72.705	72.687 ± 0.019
1085	72.602	72.621	72.731	72.651 ± 0.070
756	72.692	72.637	72.784	72.704 ± 0.074
971	72.689	72.701	72.660	72.683 ± 0.021

Unit	^{239}Pu [µmol/g]			
	Rep.1	Rep.2	Rep.3	Mean ± *s*
80	2.9997	3.0006	2.9991	2.9998 ± 0.0008
268	3.0005	3.0009	3.0019	3.0011 ± 0.0007
523	3.0013	3.0004	3.0013	3.0010 ± 0.0006
179	2.9994	3.0005	/	3.0000 ± 0.0008
429	3.0005	3.0013	3.0010	3.0009 ± 0.0004
610	3.0003	3.0009	3.0007	3.0006 ± 0.0004
894	3.0013	3.0015	3.0004	3.0011 ± 0.0006
1085	3.0007	3.0010	3.0025	3.0014 ± 0.0010
756	3.0009	3.0009	2.9999	3.0006 ± 0.0006
971	3.0000	3.0000	3.0008	3.0003 ± 0.0005

Annex 11: The results of the post-certification monitoring of the uranium and plutonium mass fraction in IRMM-1027o

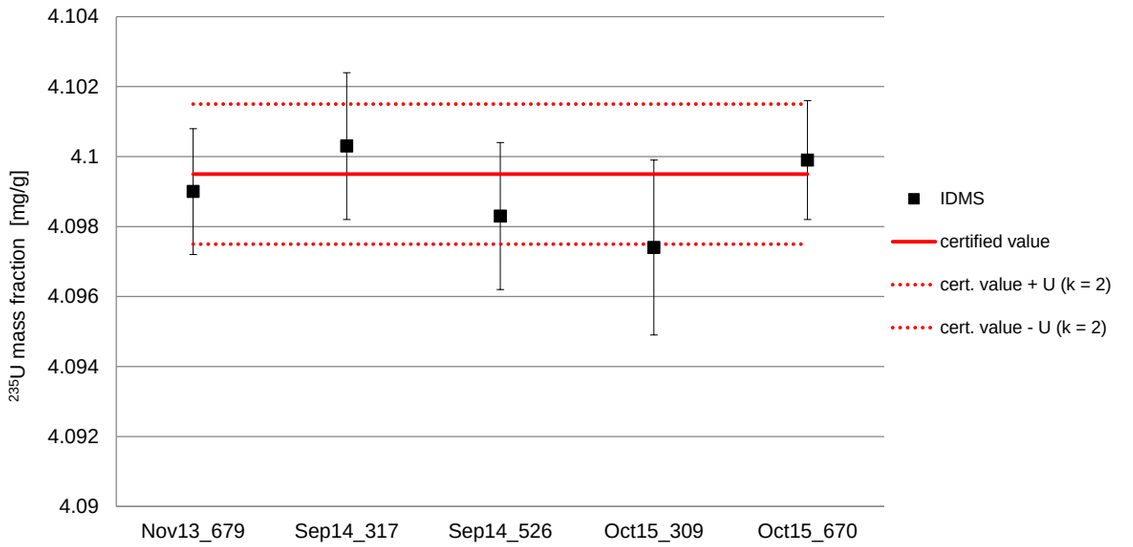

Fig 13. The mass fraction of ^{235}U in IRMM-1027o compared with the certified value for the post-certification monitoring (with expanded uncertainties, coverage factor k = 2).

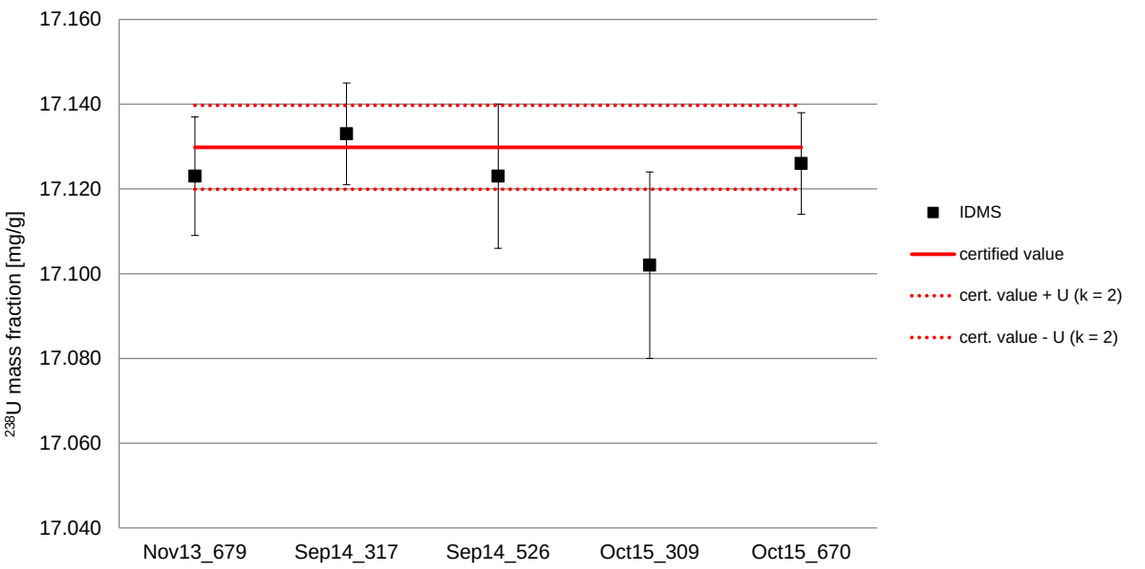

Fig 14. The mass fraction of ^{238}U in IRMM-1027o compared with the certified values for the post certification monitoring (with expanded uncertainties, coverage factor k = 2).

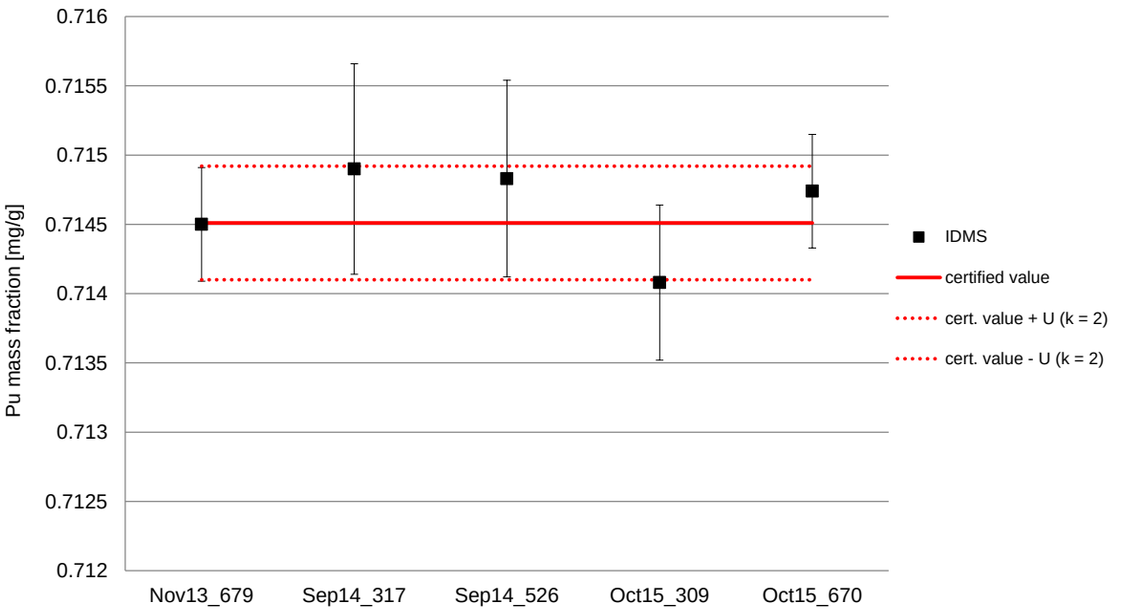

Fig 15. The mass fraction of Pu in IRMM-1027o compared with the certified values for the post certification monitoring (with expanded uncertainties, coverage factor *k* = 2).

Annex 12: The weighing certificate of the aliquots of dispensed solution of IRMM-1027r per unit before drying

European Commission	**Certificate of weighing**	Institute for Reference Materials and Measurements

E.3870 **Issued date**: 16 December 2015 **Page** 1 **of** 7

Applicant:	R. Jakopič	**Unit**: SN3S
Project:	Preparation and certification of IRMM-1027r LSD spikes	
Description:	Dispensing of IRMM-1027r mother solution into individual vials	
Weighing date:	21-25 September 2015	

The reported results apply only to the objects/samples described in this certificate and are shown in Annex.

Observations:
The dispensing and weighing were performed according to working instruction WI-D-00368 / 2 "LSD automated system equipment manual" on balance Sartorius TE124 installed in the dispensing robot box with IRMM inventory No. 2006 00290 17.

Traceability:
The certified masses are traceable to the International Kilogram Prototype via regular calibrations of the IRMM principal mass standards. The mass standard identified as H208 (cylinder + vial certificate IRMM E3162) was used to verify the balance performance in the mass determinations.

Uncertainty:
The uncertainty on the mass determinations has a value of ± 0.0006 g. The reported uncertainties is expanded uncertainties $U = k \cdot u_c$ where u_c is the combined standard uncertainty calculated according to the ISO/IEC Guide to the Expression of Uncertainty in Measurement. The coverage factor $k = 2$ corresponds to a coverage probability of about 95%.

Nuclear Chemistry Laboratory Responsible — R. Jakopič

Analyst — J. Bauwens

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Annex: Mass of the nitrate solution in the vials of IRMM-1027r before drying.

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
001	2.5182	051	2.5027	101	2.5322	151	2.5260
002	2.5177	052	2.5098	102	2.5221	152	2.5262
003	2.5007	053	2.5037	103	2.5232	153	2.5264
004	2.5101	054	2.5084	104	2.5271	154	2.5279
005	2.5063	055	2.5047	105	2.5277	155	2.5160
006	2.5062	056	2.5065	106	2.5240	156	2.5241
007	2.5108	057	2.5075	107	2.5225	157	2.5242
008	2.5070	058	2.5063	108	2.5288	158	2.5267
009	2.5097	059	2.5057	109	2.5258	159	2.5268
010	2.5076	060	2.5078	110	2.5275	160	2.5289
011	2.5023	061	2.5063	111	2.5234	161	2.5236
012	2.5104	062	2.5056	112	2.5253	162	2.5255
013	2.5081	063	2.5069	113	2.5277	163	2.5257
014	2.5068	064	2.5065	114	2.5242	164	2.5255
015	2.5101	065	2.5079	115	2.5299	165	2.5240
016	2.5067	066	2.5037	116	2.5235	166	2.5268
017	2.5059	067	2.5077	117	2.5271	167	2.5256
018	2.5109	068	2.5069	118	2.5247	168	2.5259
019	2.5069	069	2.5072	119	2.5250	169	2.5244
020	2.5093	070	2.5059	120	2.5274	170	2.5254
021	2.5058	071	2.5063	121	2.5254	171	2.5282
022	2.5021	072	2.5092	122	2.5280	172	2.5227
023	2.5086	073	2.5017	123	2.5273	173	2.5257
024	2.5070	074	2.5009	124	2.5225	174	2.5245
025	2.5073	075	2.5057	125	2.5284	175	2.5270
026	2.5082	076	2.5057	126	2.5277	176	2.5223
027	2.5085	077	2.5045	127	2.5249	177	2.5282
028	2.5088	078	2.5089	128	2.5262	178	2.5267
029	2.5047	079	2.5051	129	2.5270	179	2.5252
030	2.5046	080	2.5006	130	2.5260	180	2.5233
031	2.5081	081	2.5063	131	2.5254	181	2.5290
032	2.5070	082	2.5054	132	2.5287	182	2.5253
033	2.5040	083	2.5072	133	2.5249	183	2.5250
034	2.5030	084	2.5064	134	2.5297	184	2.5276
035	2.5054	085	2.5039	135	2.5152	185	2.5231
036	2.5090	086	2.5055	136	2.5236	186	2.5231
037	2.5063	087	2.5073	137	2.5263	187	2.5261
038	2.5064	088	2.5069	138	2.5273	188	2.5277
039	2.5084	089	2.5046	139	2.5240	189	2.5171
040	2.5045	090	2.5077	140	2.5247	190	2.5227
041	2.5050	091	2.5072	141	2.5252	191	2.5268
042	2.5051	092	2.5046	142	2.5279	192	2.5265
043	2.5077	093	2.5060	143	2.5252	193	2.5254
044	2.5089	094	2.5065	144	2.5260	194	2.5270
045	2.5044	095	2.5061	145	2.5258	195	2.5232
046	2.5040	096	2.5070	146	2.5248	196	2.5268
047	2.5050	097	2.5266	147	2.5257	197	2.5261
048	2.5006	098	2.5268	148	2.5295	198	2.5250
049	2.5026	099	2.5252	149	2.5251	199	2.5269
050	2.5091	100	2.5256	150	2.5257	200	2.5240

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Annex: Mass of the nitrate solution in the vials of IRMM-1027r before drying.

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
201	2.5249	251	2.5679	301	2.5676	351	2.5169
202	2.5216	252	2.5657	302	2.5682	352	2.5099
203	2.5279	253	2.5697	303	2.5212	353	2.5678
204	2.5252	254	2.5116	304	2.5664	354	2.5667
205	2.5272	255	2.5667	305	2.5668	355	2.5180
206	2.5245	256	2.5677	306	2.5687	356	2.5655
207	2.5246	257	2.5175	307	2.5174	357	2.5717
208	2.5243	258	2.5685	308	2.5672	358	2.5142
209	2.5286	259	2.5669	309	2.5148	359	2.5689
210	2.5229	260	2.5169	310	2.5689	360	2.5157
211	2.5214	261	2.5655	311	2.5166	361	2.5179
212	2.5183	262	2.5189	312	2.5672	362	2.5230
213	2.5235	263	2.5665	313	2.5650	363	2.5172
214	2.5670	264	2.5196	314	2.5702	364	2.5626
215	2.5703	265	2.5687	315	2.5587	365	2.5185
216	2.5161	266	2.5110	316	2.5691	366	2.5661
217	2.5218	267	2.5707	317	2.5640	367	2.5673
218	2.5128	268	2.5144	318	2.5162	368	2.5685
219	2.5713	269	2.5700	319	2.5144	369	2.5654
220	2.5656	270	2.5201	320	2.5157	370	2.5683
221	2.5686	271	2.5173	321	2.5616	371	2.5170
222	2.5680	272	2.5652	322	2.5658	372	2.5181
223	2.5179	273	2.5693	323	2.5605	373	2.5691
224	2.5677	274	2.5672	324	2.5658	374	2.5660
225	2.5647	275	2.5666	325	2.5092	375	2.5207
226	2.5670	276	2.5678	326	2.5683	376	2.5653
227	2.5668	277	2.5095	327	2.5194	377	2.5163
228	2.5152	278	2.5682	328	2.5648	378	2.5180
229	2.5192	279	2.5683	329	2.5704	379	2.5682
230	2.5711	280	2.5165	330	2.5638	380	2.5640
231	2.5170	281	2.5672	331	2.5674	381	2.5579
232	2.5681	282	2.5171	332	2.5680	382	2.5177
233	2.5682	283	[redacted]	333	2.5166	383	2.5679
234	2.5675	284	2.5231	334	2.5659	384	2.5198
235	2.5179	285	2.5708	335	2.5679	385	2.5159
236	2.5174	286	2.5696	336	2.5673	386	2.5712
237	2.5210	287	2.5143	337	2.5617	387	2.5667
238	2.5149	288	2.5724	338	2.5615	388	2.5680
239	2.5640	289	2.5662	339	2.5063	389	2.5679
240	2.5236	290	2.5705	340	2.5590	390	2.5167
241	2.5166	291	2.5201	341	2.5172	391	2.5665
242	2.5155	292	2.5665	342	2.5599	392	2.5185
243	2.5199	293	2.5645	343	2.5698	393	2.5165
244	2.5674	294	2.5709	344	2.5558	394	2.5200
245	2.5173	295	2.5654	345	2.5681	395	2.5171
246	2.5674	296	2.5170	346	2.5165	396	2.5649
247	2.5190	297	2.5183	347	2.5670	397	2.5693
248	2.5194	298	2.5659	348	2.5195	398	2.5178
249	2.5641	299	2.5222	349	2.5642	399	2.5592
250	2.5667	300	2.5139	350	2.5680	400	2.5655

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Annex: Mass of the nitrate solution in the vials of IRMM-1027r before drying.

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
0401	2.5675	451	2.5658	501	2.5684	551	2.5683
0402	2.5677	452	2.5193	502	2.5671	552	2.5659
0403	2.5680	453	2.5190	503	2.5676	553	2.5677
0404	2.5169	454	2.5181	504	2.5661	554	2.5674
0405	2.5687	455	2.5149	505	2.5206	555	2.5186
0406	2.5685	456	2.5183	506	2.5660	556	2.5677
0407	2.5139	457	2.5665	507	2.5187	557	2.5653
0408	2.5159	458	2.5715	508	2.5698	558	2.5145
0409	2.5190	459	2.5164	509	2.5166	559	2.5684
0410	2.5698	460	2.5162	510	2.5672	560	2.5186
0411	2.5663	461	2.5204	511	2.5175	561	2.5689
0412	2.5200	462	2.5194	512	2.5704	562	2.5699
0413	2.5698	463	2.5153	513	2.5645	563	2.5677
0414	2.5189	464	2.5091	514	2.5207	564	2.5175
0415	2.5670	465	2.5671	515	2.5182	565	2.5650
0416	2.5672	466	2.5174	516	2.5173	566	2.5205
0417	2.5141	467	2.5067	517	2.5180	567	2.5164
0418	2.5649	468	2.5191	518	2.5171	568	2.5674
0419	2.5168	469	2.5171	519	2.5683	569	2.5185
0420	2.5179	470	2.5674	520	2.5198	570	2.5662
0421	2.5651	471	2.5170	521	2.5549	571	2.5164
422	2.5205	472	2.5664	522	2.5213	572	2.5158
423	2.5676	473	2.5694	523	2.5694	573	2.5662
424	2.5171	474	2.5666	524	2.5672	574	2.5659
425	2.5680	475	2.5608	525	2.5704	575	2.5173
426	2.5706	476	2.5703	526	2.5175	576	2.5207
427	2.5147	477	2.5176	527	2.5633	577	2.5185
428	2.5188	478	2.5683	528	2.5616	578	2.5158
429	2.5684	479	2.5184	529	2.5690	579	2.5179
430	2.5637	480	2.5684	530	2.5128	580	2.5638
431	2.5651	481	2.5204	531	2.5205	581	2.5175
432	2.5580	482	2.5140	532	2.5653	582	2.5680
433	2.5131	483	2.5176	533	2.5674	583	2.5652
434	2.5714	484	2.5682	534	2.5201	584	2.5161
435	2.5186	485	2.5168	535	2.5690	585	2.5691
436	2.5184	486	2.5702	536	2.5657	586	2.5178
437	2.5662	487	2.5678	537	2.5688	587	2.5654
438	2.5173	488	2.5177	538	2.5681	588	2.5190
439	2.5686	489	2.5657	539	2.5672	589	2.5152
440	2.5174	490	2.5194	540	2.5697	590	2.5068
441	2.5151	491	2.5162	541	2.5675	591	2.5660
442	2.5709	492	2.5695	542	2.5682	592	2.5604
443	2.5668	493	2.5161	543	2.5204	593	2.5669
444	2.5671	494	2.5159	544	2.5161	594	2.5679
445	2.5672	495	2.5200	545	2.5184	595	2.5681
446	2.5150	496	2.5621	546	2.5161	596	2.5625
447	2.5200	497	2.5137	547	2.5191	597	2.5183
448	2.5670	498	2.5164	548	2.5685	598	2.5204
449	2.5207	499	2.5678	549	2.5675	599	2.5665
450	2.5669	500	2.5648	550	2.5675	600	2.5704

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Annex: Mass of the nitrate solution in the vials of IRMM-1027r before drying.

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
601	2.5161	651	2.5666	701	2.5197	751	2.5691
602	2.5688	652	2.5665	702	2.5128	752	2.5161
603	2.5184	653	2.5192	703	2.5204	753	2.5681
604	2.5664	654	2.5663	704	2.5636	754	2.5150
605	2.5602	655	2.5210	705	2.5673	755	2.5676
606	2.5184	656	2.5679	706	2.5190	756	2.5184
607	2.5160	657	2.5665	707	2.5659	757	2.5675
608	2.5696	658	2.5676	708	2.5695	758	2.5173
609	2.5177	659	2.5701	709	2.5184	759	2.5667
610	2.5640	660	2.5180	710	2.5178	760	2.5696
611	2.5186	661	2.5664	711	2.5176	761	2.5668
612	2.5196	662	2.5699	712	2.5685	762	2.5629
613	2.5682	663	2.5628	713	2.5680	763	2.5181
614	2.5679	664	2.5695	714	2.5663	764	2.5167
615	2.5679	665	2.5174	715	2.5158	765	2.5182
616	2.5674	666	2.5698	716	2.5196	766	2.5181
617	2.5695	667	2.5662	717	2.5671	767	2.5153
618	2.5657	668	2.5705	718	2.5670	768	2.5191
619	2.5659	669	2.5657	719	2.5705	769	2.5729
620	2.5209	670	2.5675	720	2.5656	770	2.5663
621	2.5664	671	2.5189	721	2.5168	771	2.5178
622	2.5689	672	2.5657	722	2.5185	772	2.5721
623	2.5658	673	2.5684	723	2.5197	773	2.5172
624	2.5644	674	2.5185	724	2.5165	774	2.5702
625	2.5632	675	2.5180	725	2.5126	775	2.5721
626	2.5105	676	2.5165	726	2.5646	776	2.5669
627	2.5668	677	2.5688	727	2.5172	777	2.5645
628	2.5221	678	2.5146	728	2.5200	778	2.5204
629	2.5158	679	2.5667	729	2.5183	779	2.5166
630	2.5679	680	2.5150	730	2.5147	780	2.5182
631	2.5672	681	2.5693	731	2.5185	781	2.5723
632	2.5198	682	2.5183	732	2.5711	782	2.5690
633	2.5192	683	2.5689	733	2.5653	783	2.5160
634	2.5685	684	2.5673	734	2.5697	784	2.5655
635	2.5664	685	2.5653	735	2.5178	785	2.5159
636	2.5695	686	2.5175	736	2.5661	786	2.5169
637	2.5148	687	2.5223	737	2.5183	787	2.5211
638	2.5663	688	2.5174	738	2.5196	788	2.5158
639	2.5197	689	2.5667	739	2.5183	789	2.5679
640	2.5185	690	2.5691	740	2.5654	790	2.5209
641	2.5173	691	2.5155	741	2.5206	791	2.5192
642	2.5672	692	2.5682	742	2.5640	792	2.5687
643	2.5167	693	2.5691	743	2.5686	793	2.5694
644	2.5661	694	2.5167	744	2.5689	794	2.5188
645	2.5580	695	2.5194	745	2.5171	795	2.5155
646	2.5172	696	2.5153	746	2.5651	796	2.5702
647	2.5691	697	2.5179	747	2.5164	797	2.5660
648	2.5172	698	2.5689	748	2.5205	798	2.5231
649	2.5662	699	2.5652	749	2.5186	799	2.5652
650	2.5715	700	2.5201	750	2.5160	800	2.5162

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Annex: Mass of the nitrate solution in the vials of IRMM-1027r before drying.

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
801	2.5213	851	2.5174	901	2.5188	951	2.5679
802	2.5174	852	2.5191	902	2.5199	952	2.5178
803	2.5653	853	2.5163	903	2.5665	953	2.5165
804	2.5196	854	2.5685	904	2.5198	954	2.5676
805	2.5172	855	2.5165	905	2.5222	955	2.5686
806	2.5135	856	2.5194	906	2.5679	956	2.5665
807	2.5155	857	2.5186	907	2.5156	957	2.5194
808	2.5207	858	2.5690	908	2.5720	958	2.5171
809	2.5673	859	2.5669	909	2.5697	959	2.5678
810	2.5713	860	2.5618	910	2.5194	960	2.5670
811	2.5693	861	2.5680	911	2.5672	0961	2.5679
812	2.5694	862	2.5183	912	2.5198	0962	2.5685
813	2.5688	863	2.5682	913	2.5694	0963	2.5176
814	2.5178	864	2.5213	914	2.5197	0964	2.5679
815	2.5725	865	2.5169	915	2.5190	965	2.5188
816	2.5181	866	2.5691	916	2.5167	966	2.5189
817	2.5189	867	2.5226	917	2.5678	967	2.5669
818	2.5692	868	2.5686	918	2.5675	968	2.5133
819	2.5187	869	2.5689	919	2.5192	969	2.5186
820	2.5650	870	2.5690	920	2.5148	970	2.5170
821	2.5208	871	2.5719	921	2.5559	971	2.5684
822	2.5679	872	2.5679	922	2.5186	972	2.5676
823	2.5688	873	2.5716	923	2.5181	973	2.5653
824	2.5197	874	2.5200	924	2.5681	974	2.5195
825	2.5173	875	2.5672	925	2.5667	975	2.5676
826	2.5198	876	2.5205	926	2.5211	976	2.5178
827	2.5187	877	2.5700	927	2.5675	977	2.5686
828	2.5194	878	2.5184	928	2.5677	978	2.5179
829	2.5672	879	2.5662	929	2.5667	979	2.5153
830	2.5693	880	2.5207	930	2.5161	980	2.5203
831	2.5658	881	2.5179	931	2.5212	981	2.5172
832	2.5696	882	2.5662	932	2.5664	982	2.5671
833	2.5671	883	2.5214	933	2.5659	983	2.5212
834	2.5632	884	2.5663	934	2.5196	984	2.5645
835	2.5179	885	2.5694	935	2.5182	985	2.5197
836	2.5675	886	2.5688	936	2.5665	986	2.5660
837	2.5191	887	2.5184	937	2.5121	987	2.5666
838	2.5659	888	2.5669	938	2.5671	988	2.5671
839	2.5129	889	2.5666	939	2.5682	989	2.5682
840	2.5184	890	2.5672	940	2.5657	990	2.5670
841	2.5206	891	2.5205	941	2.5202	991	2.5655
842	2.5176	892	2.5130	942	2.5660	992	2.5200
843	2.5147	893	2.5667	943	2.5154	993	2.5668
844	2.5213	894	2.5203	944	2.5709	994	2.5199
845	2.5670	895	2.5199	945	2.5157	995	2.5176
846	2.5198	896	2.5179	946	2.5696	996	2.5608
847	2.5201	897	2.5174	947	2.5187	997	2.5690
848	2.5664	898	2.5193	948	2.5677	998	2.5638
849	2.5693	899	2.5658	949	2.5161	999	2.5689
850	2.5191	900	2.5178	950	2.5181	1000	2.5190

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Annex: Mass of the nitrate solution in the vials of IRMM-1027r before drying.

Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]	Vial No.	Mass [g]
1001	2.5163	1051	2.5206	1101	2.5709	1151	2.5232
1002	2.5175	1052	2.5677	1102	2.5154	1152	2.5230
1003	2.5671	1053	2.5169	1103	2.5203		
1004	2.5190	1054	2.5690	1104	2.5195		
1005	2.5662	1055	2.5663	1105	2.5647		
1006	2.5159	1056	2.5181	1106	2.5147		
1007	2.5689	1057	2.5209	1107	2.5188		
1008	2.5700	1058	2.5188	1108	2.5669		
1009	2.5196	1059	2.5689	1109	2.5169		
1010	2.5648	1060	2.5168	1110	2.5174		
1011	2.5188	1061	2.5665	1111	2.5216		
1012	2.5703	1062	2.5638	1112	2.5646		
1013	2.5638	1063	2.5188	1113	2.5682		
1014	2.5706	1064	2.5199	1114	2.5172		
1015	2.5668	1065	2.5685	1115	2.5656		
1016	2.5179	1066	2.5174	1116	2.5192		
1017	2.5181	1067	2.5170	1117	2.5649		
1018	2.5647	1068	2.5169	1118	2.5680		
1019	2.5688	1069	2.5157	1119	2.5161		
1020	2.5122	1070	2.5214	1120	2.5162		
1021	2.5656	1071	2.5678	1121	2.5651		
1022	2.5669	1072	2.5174	1122	2.5197		
1023	2.5681	1073	2.5194	1123	2.5676		
1024	2.5205	1074	2.5168	1124	2.5177		
1025	2.5650	1075	2.5182	1125	2.5170		
1026	2.5205	1076	2.5203	1126	2.5669		
1027	2.5675	1077	2.5660	1127	2.5664		
1028	2.5166	1078	2.5684	1128	2.5654		
1029	2.5691	1079	2.5670	1129	2.5175		
1030	2.5169	1080	2.5656	1130	2.5711		
1031	2.5671	1081	2.5672	1131	2.5670		
1032	2.5198	1082	2.5674	1132	2.5179		
1033	2.5185	1083	2.5170	1133	2.5646		
1034	2.5176	1084	2.5665	1134	2.5699		
1035	2.5665	1085	2.5146	1135	2.5639		
1036	2.5194	1086	2.5660	1136	2.5664		
1037	2.5182	1087	2.5627	1137	2.5684		
1038	2.5149	1088	2.5688	1138	2.5198		
1039	2.5672	1089	2.5667	1139	2.5647		
1040	2.5184	1090	2.5184	1140	2.5162		
1041	2.5208	1091	2.5186	1141	2.5670		
1042	2.5678	1092	2.5680	1142	2.5686		
1043	2.5640	1093	2.5145	1143	2.5672		
1044	2.5683	1094	2.5218	1144	2.5177		
1045	2.5192	1095	2.5657	1145	2.5668		
1046	2.5633	1096	2.5660	1146	2.5650		
1047	2.5168	1097	2.5694	1147	2.5196		
1048	2.5188	1098	2.5181	1148	2.5143		
1049	2.5187	1099	2.5189	1149	2.5218		
1050	2.5187	1100	2.5132	1150	2.5164		

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Annex 13: Uncertainty budget for the uranium gravimetric mixture of IRMM-1027r

Uranium gravimetric mixture for IRMM-1027r

Author: Jakopic

Author: Rozle Jakopic

A uranium gravimetric mixture was prepared by dissolving natural uranium (EC NRM 101) and enriched uranium (NBL CRM 116-A) metals in nitric acid solution.

Input parameters: a) masses of the metals and the nitrate solution (E3866) b) purity of the metals (metal certificates) c) uranium isotope amount ratios of the metals (certificate) d) atomic masses for uranium isotopes from G. Audi et al., Nuclear Physics A 729, 337-676, 2003

U ingrowth from Pu MP2 metal is calculated from the measurement data (2006, IRMM) plus the ingrowth from 2006 until 01 November 2015 (reference date)

Model Equation:

{Molar mass of uranium in gravimetric mixture, IRMM-1027r}

$M_U = M_{233U} \cdot f_{233U} + M_{234U} \cdot f_{234U} + M_{235U} \cdot f_{235U} + M_{236U} \cdot f_{236U} + M_{238U} \cdot f_{238U}$;

{Isotope amount fraction in gravimetric mixture, IRMM-1027r}

$f_{233U} = R_{233U/238U} / \Sigma R_U$;

$f_{234U} = R_{234U/238U} / \Sigma R_U$;

$f_{235U} = R_{235U/238U} / \Sigma R_U$;

$f_{236U} = R_{236U/238U} / \Sigma R_U$;

$f_{238U} = 1 / \Sigma R_U$;

$\Sigma R_U = R_{233U/238U} + R_{234U/238U} + R_{235U/238U} + R_{236U/238U} + 1$;

{Isotope mass fraction in gravimetric mixture, IRMM-1027r}

$w_{233U} = f_{233U} \cdot M_{233U} / M_U$;

$w_{234U} = f_{234U} \cdot M_{234U} / M_U$;

$w_{235U} = f_{235U} \cdot M_{235U} / M_U$;

$w_{236U} = f_{236U} \cdot M_{236U} / M_U$;

$w_{238U} = f_{238U} \cdot M_{238U} / M_U$;

{Isotope amount ratios in gravimetric mixture, IRMM-1027r}

$R_{233U/238U} = n_{233U} / n_{238U}$;

$R_{234U/238U} = n_{234U} / n_{238U}$;

$R_{235U/238U} = n_{235U} / n_{238U}$;

$R_{236U/238U} = n_{236U} / n_{238U}$;

{Amount of uranium isotopes in gravimetric mixture, IRMM-1027r}

$n_{233U} = (n_{233.a} + n_{233.b} + n_{233.c})$;

$n_{234U} = (n_{234.a} + n_{234.b} + n_{234.c})$;

$n_{235U} = (n_{235.a} + n_{235.b} + n_{235.c})$;

$n_{236U} = (n_{236.a} + n_{236.b} + n_{236.c})$;

$n_{238U} = (n_{238.a} + n_{238.b} + n_{238.c})$;

{uranium mass fraction in gravimetric mixture, IRMM-1027r}

$\gamma_{Umixture} = (m_{UCRM116A} * \eta_{purityCRM116A} + m_{UEC101} * \eta_{purityEC101} + m_{UMP2}) / m_{solution1027r}$;

$\gamma_{235Umixture}=\gamma_{Umixture}*w_{235U}$;

$\gamma_{238Umixture}=\gamma_{Umixture}*w_{238U}$;

$m_{235Uvial80}=\gamma_{235Umixture}*m_{aliquot80}$;

$m_{238Uvial80}=\gamma_{238Umixture}*m_{aliquot80}$;

{uranium amount content in gravimetric mixture, IRMM-1027r}

$c_{Umixture}=\gamma_{Umixture}/M_U$;

$c_{235Umixture}=c_{Umixture}*f_{235U}$;

$c_{238Umixture}=c_{Umixture}*f_{238U}$;

{Amount of uranium isotopes in EC NRM 101}

$n_{233,a} = m_{UEC101} * \eta_{purityEC101} * f_{233Ua} / M_{Ua}$;

$n_{234,a} = m_{UEC101} * \eta_{purityEC101} * f_{234Ua} / M_{Ua}$;

$n_{235,a} = m_{UEC101} * \eta_{purityEC101} * f_{235Ua} / M_{Ua}$;

$n_{236,a} = m_{UEC101} * \eta_{purityEC101} * f_{236Ua} / M_{Ua}$;

$n_{238,a} = m_{UEC101} * \eta_{purityEC101} * f_{238Ua} / M_{Ua}$;

{Amount of uranium isotopes in NBL CRM116-A}

$n_{233,b} = m_{UCRM116A} * \eta_{purityCRM116A} * f_{233Ub} / M_{Ub}$;

$n_{234,b} = m_{UCRM116A} * \eta_{purityCRM116A} * f_{234Ub} / M_{Ub}$;

$n_{235,b} = m_{UCRM116A} * \eta_{purityCRM116A} * f_{235Ub} / M_{Ub}$;

$n_{236,b} = m_{UCRM116A} * \eta_{purityCRM116A} * f_{236Ub} / M_{Ub}$;

$n_{238,b} = m_{UCRM116A} * \eta_{purityCRM116A} * f_{238Ub} / M_{Ub}$;

{Isotope amount fraction of uranium in EC NRM 101}

$f_{233Ua} = R_{233U/238Ua}/\Sigma R_{Ua}$;

$f_{234Ua} = R_{234U/238Ua}/\Sigma R_{Ua}$;

$f_{235Ua} = R_{235U/238Ua}/\Sigma R_{Ua}$;

$f_{236Ua} = R_{236U/238Ua}/\Sigma R_{Ua}$;

$f_{238Ua} = 1/\Sigma R_{Ua}$;

$\Sigma R_{Ua} = R_{233U/238Ua} + R_{234U/238Ua} + R_{235U/238Ua} + R_{236U/238Ua} + 1$;

{Molar mass of uranium in EC NRM 101}

$M_{Ua} = M_{233U}\cdot f_{233Ua} + M_{234U}\cdot f_{234Ua} + M_{235U}\cdot f_{235Ua} + M_{236U}\cdot f_{236Ua} + M_{238U}\cdot f_{238Ua}$;

$w_{233Ua}=f_{233Ua}*M_{233U}/M_{Ua}$;

$w_{234Ua}=f_{234Ua}*M_{234U}/M_{Ua}$;

$w_{235Ua}=f_{235Ua}*M_{235U}/M_{Ua}$;

$w_{236Ua}=f_{236Ua}*M_{236U}/M_{Ua}$;

$w_{238Ua}=f_{238Ua}*M_{238U}/M_{Ua}$;

{Isotope amount fraction of uranium in NBL CRM 116-A}

$f_{233Ub} = R_{233U/235Ub}/\Sigma R_{Ub}$;

$f_{234Ub} = R_{234U/235Ub}/\Sigma R_{Ub}$;

$f_{238Ub} = R_{238U/235Ub}/\Sigma R_{Ub}$;

$f_{236Ub} = R_{236U/235Ub}/\Sigma R_{Ub}$;

$f_{235Ub} = 1/\Sigma R_{Ub}$;

$\Sigma R_{Ub} = R_{233U/235Ub} + R_{234U/235Ub} + R_{238U/235Ub} + R_{236U/235Ub} + 1$;

{Molar mass of uranium in NBL CRM 116-A}

$M_{Ub} = M_{233U} \cdot f_{233Ub} + M_{234U} \cdot f_{234Ub} + M_{235U} \cdot f_{235Ub} + M_{236U} \cdot f_{236Ub} + M_{238U} \cdot f_{238Ub}$;

$w_{233Ub} = f_{233Ub} * M_{233U}/M_{Ub}$;

$w_{234Ub} = f_{234Ub} * M_{234U}/M_{Ub}$;

$w_{235Ub} = f_{235Ub} * M_{235U}/M_{Ub}$;

$w_{236Ub} = f_{236Ub} * M_{236U}/M_{Ub}$;

$w_{238Ub} = f_{238Ub} * M_{238U}/M_{Ub}$;

List of Quantities:

Quantity	Unit	Definition
$\gamma_{Umixture}$	g/g	U mass fraction in IRMM-1027r
$\gamma_{235Umixture}$	g/g	^{235}U mass fraction in IRMM-1027r
$\gamma_{238Umixture}$	g/g	^{238}U mass fraction in IRMM-1027r
$c_{Umixture}$	mol/g	U amount content in IRMM-1027r
$c_{235Umixture}$	mol/g	^{235}U amount content in IRMM-1027r
$c_{238Umixture}$	mol/g	^{238}U amount content in IRMM-1027r
M_U	g/mol	Molar mass of U in IRMM-1027r
$R_{233U/238U}$	mol/mol	^{233}U/^{238}U amount ratio in IRMM-1027r
$R_{234U/238U}$	mol/mol	^{234}U/^{238}U amount ratio in IRMM-1027r
$R_{235U/238U}$	mol/mol	^{235}U/^{238}U amount ratio in IRMM-1027r
$R_{236U/238U}$	mol/mol	^{236}U/^{238}U amount ratio in IRMM-1027r
f_{233U}	mol/mol	^{233}U amount fraction in IRMM-1027r
f_{234U}	mol/mol	^{234}U amount fraction in IRMM-1027r
f_{235U}	mol/mol	^{235}U amount fraction in IRMM-1027r
f_{236U}	mol/mol	^{236}U amount fraction in IRMM-1027r
f_{238U}	mol/mol	^{238}U amount fraction in IRMM-1027r
w_{233U}	g/g	^{233}U mass fraction in IRMM-1027r
w_{234U}	g/g	^{234}U mass fraction in IRMM-1027r
w_{235U}	g/g	^{235}U mass fraction in IRMM-1027r
w_{236U}	g/g	^{236}U mass fraction in IRMM-1027r
w_{238U}	g/g	^{238}U mass fraction in IRMM-1027r
n_{233U}	mol	Amount of U-233 in the mixture
n_{234U}	mol	Amount of U-234 in the mixture
n_{235U}	mol	Amount of U-235 in the mixture
n_{236U}	mol	Amount of U-236 in the mixture

Quantity	Unit	Definition
n_{238U}	mol	Amount of U-238 in the mixture
M_{233U}	g/mol	Atomic mass of ^{233}U
M_{234U}	g/mol	Atomic mass of ^{234}U
M_{235U}	g/mol	Atomic mass of ^{235}U
M_{236U}	g/mol	Atomic mass of ^{236}U
M_{238U}	g/mol	Atomic mass of ^{238}U
$m_{solution1027r}$	g	Mass of gravimetric mixture, IRMM-1027r
m_{UEC101}	g	Mass of natural uranium metal, EC-NRM 101
$\eta_{purityEC101}$	g/g	Purity of natural uranium metal, EC NRM 101
$m_{UCRM116A}$	g	Mass of enriched uranium metal, NBL CRM-116A
$\eta_{purityCRM116A}$	g/g	Purity of enriched uranium metal, NBL CRM-116A
M_{Ua}	g/mol	Molar mass of U in EC NRM 101
f_{233Ua}	mol/mol	^{233}U amount fraction in EC NRM 101
f_{234Ua}	mol/mol	^{234}U amount fraction in EC NRM 101
f_{235Ua}	mol/mol	^{235}U amount fraction in EC NRM 101
f_{236Ua}	mol/mol	^{236}U amount fraction in EC NRM 101
f_{238Ua}	mol/mol	^{238}U amount fraction in EC NRM 101
M_{Ub}	g/mol	Molar mass of U in NBL CRM-116A
f_{233Ub}	mol/mol	^{233}U amount fraction in NBL CRM 116-A
f_{234Ub}	mol/mol	^{234}U amount fraction in NBL CRM 116-A
f_{235Ub}	mol/mol	^{235}U amount fraction in NBL CRM 116-A
f_{236Ub}	mol/mol	^{236}U amount fraction in NBL CRM 116-A
f_{238Ub}	mol/mol	^{238}U amount fraction in NBL CRM 116-A
$n_{233,a}$	mol	^{233} U amount in EC NRM 101
$n_{234,a}$	mol	^{234} U amount in EC NRM 101
$n_{235,a}$	mol	^{235} U amount in EC NRM 101
$n_{236,a}$	mol	^{236} U amount in EC NRM 101
$n_{238,a}$	mol	^{238} U amount in EC NRM 101
$n_{233,b}$	mol	^{233} U amount in NBL CRM 116-A
$n_{234,b}$	mol	^{234} U amount in NBL CRM 116-A
$n_{235,b}$	mol	^{235} U amount in NBL CRM 116-A
$n_{236,b}$	mol	^{236} U amount in NBL CRM 116-A
$n_{238,b}$	mol	^{238} U amount in NBL CRM 116-A
$R_{233U/238Ua}$	mol/mol	$^{233}U/^{238}U$ amount ratio in EC NRM 101
$R_{234U/238Ua}$	mol/mol	$^{234}U/^{238}U$ amount ratio in EC NRM 101
$R_{235U/238Ua}$	mol/mol	$^{235}U/^{238}U$ amount ratio in EC NRM 101
$R_{236U/238Ua}$	mol/mol	$^{236}U/^{238}U$ amount ratio in EC NRM 101
$R_{233U/235Ub}$	mol/mol	$^{233}U/^{235}U$ amount ratio in NBL CRM 116-A

Quantity	Unit	Definition
$R_{234U/235Ub}$	mol/mol	$^{234}U/^{235}U$ amount ratio in NBL CRM 116-A
$R_{238U/235Ub}$	mol/mol	$^{238}U/^{235}U$ amount ratio in NBL CRM 116-A
$R_{236U/235Ub}$	mol/mol	$^{236}U/^{235}U$ amount ratio in NBL CRM 116-A
ΣR_U	mol/mol	Sum of amount ratios in gravimteric mixture, IRMM-1027r
ΣR_{Ua}	mol/mol	Sum of amount ratios in EC- NRM 101
ΣR_{Ub}	mol/mol	Sum of amount ratios in NBL CRM 116-A
w_{233Ua}	g/g	^{233}U mass fraction in EC 101
w_{234Ua}	g/g	^{234}U mass fraction in EC 101
w_{235Ua}	g/g	^{235}U mass fraction in EC 101
w_{236Ua}	g/g	^{236}U mass fraction in EC 101
w_{238Ua}	g/g	^{238}U mass fraction in EC 101
w_{233Ub}	g/g	^{233}U mass fraction in CRM 116-A
w_{234Ub}	g/g	^{234}U mass fraction in CRM 116-A
w_{235Ub}	g/g	^{235}U mass fraction in CRM 116-A
w_{236Ub}	g/g	^{236}U mass fraction in CRM 116-A
w_{238Ub}	g/g	^{238}U mass fraction in CRM 116-A
$n_{234,c}$	mol	^{234}U amount ingrowth from Pu MP2
$n_{235,c}$	mol	^{235}U amount ingrowth from Pu MP2
$n_{236,c}$	mol	^{236}U amount ingrowth from Pu MP2
$n_{233,c}$	mol	^{233}U amount ingrowth from Pu MP2
$n_{238,c}$	mol	^{238}U amount ingrowth from Pu MP2
m_{UMP2}	g	mass of total ingrown U from Pu MP2
$m_{235Uvial80}$	g	mass of ^{235}U in vial No 80
$m_{aliquot80}$	g	mass of an aliquot in vial No 80 (dispensed mass)
$m_{238Uvial80}$	g	mass of ^{238}U in vial No 80

M_{233U}: Type B normal distribution
Value: 233.0396352 g/mol
Expanded Uncertainty: 0.0000058 g/mol
Coverage Factor: 2

G. Audi et al., The AME2003 atomic mass evaluation, Nuclear Physics A 729, 337-676, 2003

M_{234U}: Type B normal distribution
Value: 234.0409521 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al., The AME2003 atomic mass evaluation, Nuclear Physics A 729, 337-676, 2003

M_{235U}: Type B normal distribution
Value: 235.0439299 g/mol
Expanded Uncertainty: 0.00000040 g/mol
Coverage Factor: 2

G. Audi et al., The AME2003 atomic mass evaluation, Nuclear Physics A 729, 337-676, 2003

$\mathbf{M}_{236U}$: Type B normal distribution
Value: 236.0455680 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al., The AME2003 atomic mass evaluation, Nuclear Physics A 729, 337-676, 2003

$\mathbf{M}_{238U}$: Type B normal distribution
Value: 238.0507882 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al., The AME2003 atomic mass evaluation, Nuclear Physics A 729, 337-676, 2003

$\mathbf{m}_{solution1027r}$: Type B normal distribution
Value: 3005.42 g
Expanded Uncertainty: 0.025 g
Coverage Factor: 2

E3866

$\mathbf{m}_{UEC101}$: Type B normal distribution
Value: 51.77549 g
Expanded Uncertainty: 0.00009 g
Coverage Factor: 2

E3866

$\boldsymbol{\eta}_{purityEC101}$: Type B normal distribution
Value: 0.99985 g/g
Expanded Uncertainty: 0.00005 g/g
Coverage Factor: 2

EC NRM 101 certificate

$\mathbf{m}_{UCRM116A}$: Type B normal distribution
Value: 12.40821 g
Expanded Uncertainty: 0.00007 g
Coverage Factor: 2

E3866

$\boldsymbol{\eta}_{purityCRM116A}$: Type B normal distribution
Value: 0.99945 g/g
Expanded Uncertainty: 0.00014 g/g
Coverage Factor: 2.4

NBL CRM 116-A certificate (coverage factor 2.4)

$\mathbf{R}_{233U/238Ua}$: Type B normal distribution
Value: 0 mol/mol
Expanded Uncertainty: 0 mol/mol
Coverage Factor: 2

Certificate of isotopic coposition (IRMM, W. De Bolle)

$\mathbf{R}_{234U/238Ua}$: Type B normal distribution
Value: 0.00005548 mol/mol
Expanded Uncertainty: 0.00000022 mol/mol
Coverage Factor: 2

Certificate of isotopic coposition (IRMM, W. De Bolle)

$R_{235U/238Ua}$: Type B normal distribution
Value: 0.0072593 mol/mol
Expanded Uncertainty: 0.0000036 mol/mol
Coverage Factor: 2

Certificate of isotopic coposition (IRMM, W. De Bolle)

$R_{236U/238Ua}$: Type B normal distribution
Value: 0.000000151 mol/mol
Expanded Uncertainty: 0.000000040 mol/mol
Coverage Factor: 2

Certificate of isotopic coposition (IRMM, W. De Bolle)

$R_{233U/235Ub}$: Type B normal distribution
Value: 0.0000003863 mol/mol
Expanded Uncertainty: 0.0000000086 mol/mol
Coverage Factor: 3.3

CRM 116-A certificate (coverage factor k= 3.3)

$R_{234U/235Ub}$: Type B normal distribution
Value: 0.0115836 mol/mol
Expanded Uncertainty: 0.0000097 mol/mol
Coverage Factor: 2

CRM 116-A certificate

$R_{238U/235Ub}$: Type B normal distribution
Value: 0.051277 mol/mol
Expanded Uncertainty: 0.000041 mol/mol
Coverage Factor: 2

CRM 116-A certificate

$R_{236U/235Ub}$: Type B normal distribution
Value: 0.0094713 mol/mol
Expanded Uncertainty: 0.0000077 mol/mol
Coverage Factor: 2

CRM 116-A certificate

$n_{234.c}$: Import
Filename: U ingrowth from Pu MP2.smu
Symbol: n_{234U}Total

$n_{235.c}$: Import
Filename: U ingrowth from Pu MP2.smu
Symbol: n_{235U}Total

$n_{236.c}$: Import
Filename: U ingrowth from Pu MP2.smu
Symbol: n_{236U}Total

$n_{233.c}$: Type B normal distribution
Value: 0 mol
Expanded Uncertainty: 0 mol
Coverage Factor: 2

$n_{238,c}$:
Import
Filename: U ingrowth from Pu MP2.smu
Symbol: n_{238U}Total

m_{UMP2}:
Import
Filename: U ingrowth from Pu MP2.smu
Symbol: m_UTotal

$m_{aliquot80}$:
Type B normal distribution
Value: 2.5005784 g
Expanded Uncertainty: 0.0006000 g
Coverage Factor: 2

E 3870

Input Correlation:

	$n_{234,c}$	$n_{235,c}$	$n_{236,c}$	$n_{238,c}$	m_{UMP2}
$n_{234,c}$	1	0.2540	0.1905	0.0030	0.2827
$n_{235,c}$	0.2540	1	0.7082	0.0113	0.9970
$n_{236,c}$	0.1905	0.7082	1	0.0085	0.7569
$n_{238,c}$	0.0030	0.0113	0.0085	1	0.0113
m_{UMP2}	0.2827	0.9970	0.7569	0.0113	1

Interim Results:

Quantity	Value	Standard Uncertainty
f_{233U}	$70.296 \cdot 10^{-9}$ mol/mol	$474 \cdot 10^{-12}$ mol/mol
f_{234U}	$2.152489 \cdot 10^{-3}$ mol/mol	$885 \cdot 10^{-9}$ mol/mol
f_{235U}	0.1878028 mol/mol	$10.0 \cdot 10^{-6}$ mol/mol
f_{236U}	$1.726135 \cdot 10^{-3}$ mol/mol	$701 \cdot 10^{-9}$ mol/mol
f_{238U}	0.8083185 mol/mol	$10.2 \cdot 10^{-6}$ mol/mol
n_{233U}	$18.996 \cdot 10^{-9}$ mol	$128 \cdot 10^{-12}$ mol
n_{234U}	$581.654 \cdot 10^{-6}$ mol	$240 \cdot 10^{-9}$ mol
n_{235U}	0.05074886 mol	$3.06 \cdot 10^{-6}$ mol
n_{236U}	$466.443 \cdot 10^{-6}$ mol	$190 \cdot 10^{-9}$ mol
n_{238U}	0.21842716 mol	$5.50 \cdot 10^{-6}$ mol
M_{Ua}	238.02889787 g/mol	$5.71 \cdot 10^{-6}$ g/mol
f_{234Ua}	$55.077 \cdot 10^{-6}$ mol/mol	$109 \cdot 10^{-9}$ mol/mol
f_{235Ua}	$7.20658 \cdot 10^{-3}$ mol/mol	$1.77 \cdot 10^{-6}$ mol/mol
f_{236Ua}	$149.9 \cdot 10^{-9}$ mol/mol	$19.9 \cdot 10^{-9}$ mol/mol
f_{238Ua}	0.99273819 mol/mol	$1.78 \cdot 10^{-6}$ mol/mol
M_{Ub}	235.1857242 g/mol	$55.1 \cdot 10^{-6}$ g/mol
f_{233Ub}	$360.24 \cdot 10^{-9}$ mol/mol	$2.43 \cdot 10^{-9}$ mol/mol
f_{234Ub}	0.01080225 mol/mol	$4.48 \cdot 10^{-6}$ mol/mol
f_{235Ub}	0.9325468 mol/mol	$18.6 \cdot 10^{-6}$ mol/mol
f_{236Ub}	$8.83243 \cdot 10^{-3}$ mol/mol	$3.56 \cdot 10^{-6}$ mol/mol
f_{238Ub}	0.0478182 mol/mol	$18.2 \cdot 10^{-6}$ mol/mol
$n_{234,a}$	$11.9784 \cdot 10^{-6}$ mol	$23.8 \cdot 10^{-9}$ mol
$n_{235,a}$	$1.567324 \cdot 10^{-3}$ mol	$388 \cdot 10^{-9}$ mol
$n_{236,a}$	$32.60 \cdot 10^{-9}$ mol	$4.32 \cdot 10^{-9}$ mol
$n_{238,a}$	0.21590570 mol	$5.42 \cdot 10^{-6}$ mol
$n_{233,b}$	$18.996 \cdot 10^{-9}$ mol	$128 \cdot 10^{-12}$ mol
$n_{234,b}$	$569.605 \cdot 10^{-6}$ mol	$239 \cdot 10^{-9}$ mol
$n_{235,b}$	0.04917336 mol	$3.04 \cdot 10^{-6}$ mol
$n_{236,b}$	$465.736 \cdot 10^{-6}$ mol	$190 \cdot 10^{-9}$ mol
$n_{238,b}$	$2.521462 \cdot 10^{-3}$ mol	$971 \cdot 10^{-9}$ mol
ΣR_U	1.2371362 mol/mol	$15.6 \cdot 10^{-6}$ mol/mol
ΣR_{Ua}	1.00731493 mol/mol	$1.80 \cdot 10^{-6}$ mol/mol
ΣR_{Ub}	1.0723323 mol/mol	$21.4 \cdot 10^{-6}$ mol/mol
w_{234Ua}	$54.154 \cdot 10^{-6}$ g/g	$107 \cdot 10^{-9}$ g/g
w_{235Ua}	$7.11621 \cdot 10^{-3}$ g/g	$1.75 \cdot 10^{-6}$ g/g
w_{236Ua}	$148.7 \cdot 10^{-9}$ g/g	$19.7 \cdot 10^{-9}$ g/g

Quantity	Value	Standard Uncertainty
w_{238Ua}	0.99282949 g/g	$1.76 \cdot 10^{-6}$ g/g
w_{233Ub}	$356.96 \cdot 10^{-9}$ g/g	$2.41 \cdot 10^{-9}$ g/g
w_{234Ub}	0.01074967 g/g	$4.46 \cdot 10^{-6}$ g/g
w_{235Ub}	0.9319845 g/g	$18.8 \cdot 10^{-6}$ g/g
w_{236Ub}	$8.86472 \cdot 10^{-3}$ g/g	$3.58 \cdot 10^{-6}$ g/g
w_{238Ub}	0.0484007 g/g	$18.4 \cdot 10^{-6}$ g/g

Uncertainty Budgets:

$\gamma_{235Umixture}$: ^{235}U mass fraction in IRMM-1027r

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$\gamma_{Umixture}$	0.021351827 g/g	$502 \cdot 10^{-9}$ g/g				
M_U	237.4739989 g/mol	$30.7 \cdot 10^{-6}$ g/mol				
f_{233U}	$70.296 \cdot 10^{-9}$ mol/mol	$474 \cdot 10^{-12}$ mol/mol				
f_{234U}	$2.152489 \cdot 10^{-3}$ mol/mol	$885 \cdot 10^{-9}$ mol/mol				
f_{235U}	0.1878028 mol/mol	$10.0 \cdot 10^{-6}$ mol/mol				
f_{236U}	$1.726135 \cdot 10^{-3}$ mol/mol	$701 \cdot 10^{-9}$ mol/mol				
f_{238U}	0.8083185 mol/mol	$10.2 \cdot 10^{-6}$ mol/mol				
w_{235U}	0.18588106 g/g	$9.96 \cdot 10^{-6}$ g/g				
n_{233U}	$18.996 \cdot 10^{-9}$ mol	$128 \cdot 10^{-12}$ mol				
n_{234U}	$581.654 \cdot 10^{-6}$ mol	$240 \cdot 10^{-9}$ mol				
n_{235U}	0.05074886 mol	$3.06 \cdot 10^{-6}$ mol				
n_{236U}	$466.443 \cdot 10^{-6}$ mol	$190 \cdot 10^{-9}$ mol				
n_{238U}	0.21842716 mol	$5.50 \cdot 10^{-6}$ mol				
M_{233U}	233.03963520 g/mol	$2.90 \cdot 10^{-6}$ g/mol	normal	$-5.9 \cdot 10^{-12}$	$-17 \cdot 10^{-18}$ g/g	0.0 %
M_{234U}	234.04095210 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-180 \cdot 10^{-9}$	$-350 \cdot 10^{-15}$ g/g	0.0 %
M_{235U}	235.043929900 g/mol	$200 \cdot 10^{-9}$ g/mol	normal	$1.6 \cdot 10^{-6}$	$330 \cdot 10^{-15}$ g/g	0.0 %
M_{236U}	236.04556800 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-140 \cdot 10^{-9}$	$-290 \cdot 10^{-15}$ g/g	0.0 %
M_{238U}	238.05078820 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-1.3 \cdot 10^{-6}$	$-2.6 \cdot 10^{-12}$ g/g	0.0 %
$m_{solution1027r}$	3005.4200 g	0.0125 g	normal	$-1.3 \cdot 10^{-6}$	$-17 \cdot 10^{-9}$ g/g	0.5 %
m_{UEC101}	51.7754900 g	$45.0 \cdot 10^{-6}$ g	normal	$2.4 \cdot 10^{-6}$	$110 \cdot 10^{-12}$ g/g	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	$120 \cdot 10^{-6}$	$3.1 \cdot 10^{-9}$ g/g	0.0 %
$m_{UCRM116A}$	12.4082100 g	$35.0 \cdot 10^{-6}$ g	normal	$310 \cdot 10^{-6}$	$11 \cdot 10^{-9}$ g/g	0.2 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3 \cdot 10^{-6}$ g/g	normal	$3.8 \cdot 10^{-3}$	$220 \cdot 10^{-9}$ g/g	87.3 %
M_{Ua}	238.02889787 g/mol	$5.71 \cdot 10^{-6}$ g/mol				
f_{233Ua}	0.0 mol/mol	0.0 mol/mol				
f_{234Ua}	$55.077 \cdot 10^{-6}$ mol/mol	$109 \cdot 10^{-9}$ mol/mol				

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
f_{235Ua}	$7.20658 \cdot 10^{-3}$ mol/mol	$1.77 \cdot 10^{-6}$ mol/mol				
f_{236Ua}	$149.9 \cdot 10^{-9}$ mol/mol	$19.9 \cdot 10^{-9}$ mol/mol				
f_{238Ua}	0.99273819 mol/mol	$1.78 \cdot 10^{-6}$ mol/mol				
M_{Ub}	235.1857242 g/mol	$55.1 \cdot 10^{-6}$ g/mol				
f_{233Ub}	$360.24 \cdot 10^{-9}$ mol/mol	$2.43 \cdot 10^{-9}$ mol/mol				
f_{234Ub}	0.01080225 mol/mol	$4.48 \cdot 10^{-6}$ mol/mol				
f_{235Ub}	0.9325468 mol/mol	$18.6 \cdot 10^{-6}$ mol/mol				
f_{236Ub}	$8.83243 \cdot 10^{-3}$ mol/mol	$3.56 \cdot 10^{-6}$ mol/mol				
f_{238Ub}	0.0478182 mol/mol	$18.2 \cdot 10^{-6}$ mol/mol				
$n_{233,a}$	0.0 mol	0.0 mol				
$n_{234,a}$	$11.9784 \cdot 10^{-6}$ mol	$23.8 \cdot 10^{-9}$ mol				
$n_{235,a}$	$1.567324 \cdot 10^{-3}$ mol	$388 \cdot 10^{-9}$ mol				
$n_{236,a}$	$32.60 \cdot 10^{-9}$ mol	$4.32 \cdot 10^{-9}$ mol				
$n_{238,a}$	0.21590570 mol	$5.42 \cdot 10^{-6}$ mol				
$n_{233,b}$	$18.996 \cdot 10^{-9}$ mol	$128 \cdot 10^{-12}$ mol				
$n_{234,b}$	$569.605 \cdot 10^{-6}$ mol	$239 \cdot 10^{-9}$ mol				
$n_{235,b}$	0.04917336 mol	$3.04 \cdot 10^{-6}$ mol				
$n_{236,b}$	$465.736 \cdot 10^{-6}$ mol	$190 \cdot 10^{-9}$ mol				
$n_{238,b}$	$2.521462 \cdot 10^{-3}$ mol	$971 \cdot 10^{-9}$ mol				
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 g/g	0.0 %
$R_{234U/238Ua}$	$55.480 \cdot 10^{-6}$ mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	$-120 \cdot 10^{-6}$	$-13 \cdot 10^{-12}$ g/g	0.0 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	0.017	$30 \cdot 10^{-9}$ g/g	1.6 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	$-120 \cdot 10^{-6}$	$-2.4 \cdot 10^{-12}$ g/g	0.0 %
$R_{233U/235Ub}$	$386.30 \cdot 10^{-9}$ mol/mol	$2.61 \cdot 10^{-9}$ mol/mol	normal	$-3.6 \cdot 10^{-3}$	$-9.3 \cdot 10^{-12}$ g/g	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85 \cdot 10^{-6}$ mol/mol	normal	$-3.6 \cdot 10^{-3}$	$-17 \cdot 10^{-9}$ g/g	0.5 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5 \cdot 10^{-6}$ mol/mol	normal	$-3.6 \cdot 10^{-3}$	$-74 \cdot 10^{-9}$ g/g	9.6 %

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$R_{236U/235Ub}$	$9.47130 \cdot 10^{-3}$ mol/mol	$3.85 \cdot 10^{-6}$ mol/mol	normal	$-3.6 \cdot 10^{-3}$	$-14 \cdot 10^{-9}$ g/g	0.3 %
ΣR_U	1.2371362 mol/mol	$15.6 \cdot 10^{-6}$ mol/mol				
ΣR_{Ua}	1.00731493 mol/mol	$1.80 \cdot 10^{-6}$ mol/mol				
ΣR_{Ub}	1.0723323 mol/mol	$21.4 \cdot 10^{-6}$ mol/mol				
$n_{234,c}$	$71.527 \cdot 10^{-9}$ mol	$103 \cdot 10^{-12}$ mol		-0.014	$-1.5 \cdot 10^{-12}$ g/g	0.0 %
$n_{235,c}$	$8.18101 \cdot 10^{-6}$ mol	$3.11 \cdot 10^{-9}$ mol		0.064	$200 \cdot 10^{-12}$ g/g	0.0 %
$n_{236,c}$	$675.004 \cdot 10^{-9}$ mol	$342 \cdot 10^{-12}$ mol		-0.015	$-5.0 \cdot 10^{-12}$ g/g	0.0 %
$n_{233,c}$	0.0 mol	0.0 mol	normal	0.0	0.0 g/g	0.0 %
$n_{238,c}$	$12.320 \cdot 10^{-12}$ mol	$118 \cdot 10^{-15}$ mol		-0.015	$-1.7 \cdot 10^{-15}$ g/g	0.0 %
m_{UMP2}	$2.098971 \cdot 10^{-3}$ g	$797 \cdot 10^{-9}$ g		$62 \cdot 10^{-6}$	$49 \cdot 10^{-12}$ g/g	0.0 %
$\gamma_{235Umixture}$	$3.968900 \cdot 10^{-3}$ g/g	$240 \cdot 10^{-9}$ g/g				

$\gamma_{238Umixture}$: ^{238}U mass fraction in IRMM-1027r

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$\gamma_{Umixture}$	0.021351827 g/g	$502 \cdot 10^{-9}$ g/g				
M_U	237.4739989 g/mol	$30.7 \cdot 10^{-6}$ g/mol				
f_{233U}	$70.296 \cdot 10^{-9}$ mol/mol	$474 \cdot 10^{-12}$ mol/mol				
f_{234U}	$2.152489 \cdot 10^{-3}$ mol/mol	$885 \cdot 10^{-9}$ mol/mol				
f_{235U}	0.1878028 mol/mol	$10.0 \cdot 10^{-6}$ mol/mol				
f_{236U}	$1.726135 \cdot 10^{-3}$ mol/mol	$701 \cdot 10^{-9}$ mol/mol				
f_{238U}	0.8083185 mol/mol	$10.2 \cdot 10^{-6}$ mol/mol				
w_{238U}	0.8102817 g/g	$10.1 \cdot 10^{-6}$ g/g				
n_{233U}	$18.996 \cdot 10^{-9}$ mol	$128 \cdot 10^{-12}$ mol				
n_{234U}	$581.654 \cdot 10^{-6}$ mol	$240 \cdot 10^{-9}$ mol				
n_{235U}	0.05074886 mol	$3.06 \cdot 10^{-6}$ mol				
n_{236U}	$466.443 \cdot 10^{-6}$ mol	$190 \cdot 10^{-9}$ mol				
n_{238U}	0.21842716 mol	$5.50 \cdot 10^{-6}$ mol				
M_{233U}	233.03963520 g/mol	$2.90 \cdot 10^{-6}$ g/mol	normal	$-310 \cdot 10^{-15}$	$-890 \cdot 10^{-21}$ g/g	0.0 %
M_{234U}	234.04095210 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-13 \cdot 10^{-9}$	$-26 \cdot 10^{-15}$ g/g	0.0 %
M_{235U}	235.043929900 g/mol	$200 \cdot 10^{-9}$ g/mol	normal	$-1.3 \cdot 10^{-6}$	$-260 \cdot 10^{-15}$ g/g	0.0 %
M_{236U}	236.04556800 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-7.7 \cdot 10^{-9}$	$-15 \cdot 10^{-15}$ g/g	0.0 %
M_{238U}	238.05078820 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$1.3 \cdot 10^{-6}$	$2.6 \cdot 10^{-12}$ g/g	0.0 %
$m_{solution1027r}$	3005.4200 g	0.0125 g	normal	$-5.8 \cdot 10^{-6}$	$-72 \cdot 10^{-9}$ g/g	2.7 %
m_{UEC101}	51.7754900 g	$45.0 \cdot 10^{-6}$ g	normal	$330 \cdot 10^{-6}$	$15 \cdot 10^{-9}$ g/g	0.1 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	0.017	$430 \cdot 10^{-9}$ g/g	93.7 %
$m_{UCRM116A}$	12.4082100 g	$35.0 \cdot 10^{-6}$ g	normal	$16 \cdot 10^{-6}$	$560 \cdot 10^{-12}$ g/g	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3 \cdot 10^{-6}$ g/g	normal	$200 \cdot 10^{-6}$	$12 \cdot 10^{-9}$ g/g	0.0 %
M_{Ua}	238.02889787 g/mol	$5.71 \cdot 10^{-6}$ g/mol				
f_{233Ua}	0.0 mol/mol	0.0 mol/mol				
f_{234Ua}	$55.077 \cdot 10^{-6}$ mol/mol	$109 \cdot 10^{-9}$ mol/mol				

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
f_{235Ua}	$7.20658 \cdot 10^{-3}$ mol/mol	$1.77 \cdot 10^{-6}$ mol/mol				
f_{236Ua}	$149.9 \cdot 10^{-9}$ mol/mol	$19.9 \cdot 10^{-9}$ mol/mol				
f_{238Ua}	0.99273819 mol/mol	$1.78 \cdot 10^{-6}$ mol/mol				
M_{Ub}	235.1857242 g/mol	$55.1 \cdot 10^{-6}$ g/mol				
f_{233Ub}	$360.24 \cdot 10^{-9}$ mol/mol	$2.43 \cdot 10^{-9}$ mol/mol				
f_{234Ub}	0.01080225 mol/mol	$4.48 \cdot 10^{-6}$ mol/mol				
f_{235Ub}	0.9325468 mol/mol	$18.6 \cdot 10^{-6}$ mol/mol				
f_{236Ub}	$8.83243 \cdot 10^{-3}$ mol/mol	$3.56 \cdot 10^{-6}$ mol/mol				
f_{238Ub}	0.0478182 mol/mol	$18.2 \cdot 10^{-6}$ mol/mol				
$n_{233,a}$	0.0 mol	0.0 mol				
$n_{234,a}$	$11.9784 \cdot 10^{-6}$ mol	$23.8 \cdot 10^{-9}$ mol				
$n_{235,a}$	$1.567324 \cdot 10^{-3}$ mol	$388 \cdot 10^{-9}$ mol				
$n_{236,a}$	$32.60 \cdot 10^{-9}$ mol	$4.32 \cdot 10^{-9}$ mol				
$n_{238,a}$	0.21590570 mol	$5.42 \cdot 10^{-6}$ mol				
$n_{233,b}$	$18.996 \cdot 10^{-9}$ mol	$128 \cdot 10^{-12}$ mol				
$n_{234,b}$	$569.605 \cdot 10^{-6}$ mol	$239 \cdot 10^{-9}$ mol				
$n_{235,b}$	0.04917336 mol	$3.04 \cdot 10^{-6}$ mol				
$n_{236,b}$	$465.736 \cdot 10^{-6}$ mol	$190 \cdot 10^{-9}$ mol				
$n_{238,b}$	$2.521462 \cdot 10^{-3}$ mol	$971 \cdot 10^{-9}$ mol				
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 g/g	0.0 %
$R_{234U/238Ua}$	$55.480 \cdot 10^{-6}$ mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	-0.017	$-1.8 \cdot 10^{-9}$ g/g	0.0 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	-0.017	$-30 \cdot 10^{-9}$ g/g	0.5 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	-0.017	$-340 \cdot 10^{-12}$ g/g	0.0 %
$R_{233U/235Ub}$	$386.30 \cdot 10^{-9}$ mol/mol	$2.61 \cdot 10^{-9}$ mol/mol	normal	$-180 \cdot 10^{-6}$	$-480 \cdot 10^{-15}$ g/g	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85 \cdot 10^{-6}$ mol/mol	normal	$-190 \cdot 10^{-6}$	$-900 \cdot 10^{-12}$ g/g	0.0 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5 \cdot 10^{-6}$ mol/mol	normal	$3.7 \cdot 10^{-3}$	$76 \cdot 10^{-9}$ g/g	3.0 %

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$R_{236U/235Ub}$	$9.47130 \cdot 10^{-3}$ mol/mol	$3.85 \cdot 10^{-6}$ mol/mol	normal	$-190 \cdot 10^{-6}$	$-720 \cdot 10^{-12}$ g/g	0.0 %
ΣR_U	1.2371362 mol/mol	$15.6 \cdot 10^{-6}$ mol/mol				
ΣR_{Ua}	1.00731493 mol/mol	$1.80 \cdot 10^{-6}$ mol/mol				
ΣR_{Ub}	1.0723323 mol/mol	$21.4 \cdot 10^{-6}$ mol/mol				
$n_{234,c}$	$71.527 \cdot 10^{-9}$ mol	$103 \cdot 10^{-12}$ mol		-0.063	$-6.5 \cdot 10^{-12}$ g/g	0.0 %
$n_{235,c}$	$8.18101 \cdot 10^{-6}$ mol	$3.11 \cdot 10^{-9}$ mol		-0.063	$-200 \cdot 10^{-12}$ g/g	0.0 %
$n_{236,c}$	$675.004 \cdot 10^{-9}$ mol	$342 \cdot 10^{-12}$ mol		-0.064	$-22 \cdot 10^{-12}$ g/g	0.0 %
$n_{233,c}$	0.0 mol	0.0 mol	normal	0.0	0.0 g/g	0.0 %
$n_{238,c}$	$12.320 \cdot 10^{-12}$ mol	$118 \cdot 10^{-15}$ mol		0.015	$1.8 \cdot 10^{-15}$ g/g	0.0 %
m_{UMP2}	$2.098971 \cdot 10^{-3}$ g	$797 \cdot 10^{-9}$ g		$270 \cdot 10^{-6}$	$210 \cdot 10^{-12}$ g/g	0.0 %
$\gamma_{238Umixture}$	0.017300996 g/g	$442 \cdot 10^{-9}$ g/g				

$R_{233U/238U}$: $^{233}U/^{238}U$ amount ratio in IRMM-1027r

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
n_{233U}	$18.996 \cdot 10^{-9}$ mol	$128 \cdot 10^{-12}$ mol				
n_{238U}	0.21842716 mol	$5.50 \cdot 10^{-6}$ mol				
M_{233U}	233.03963520 g/mol	$2.90 \cdot 10^{-6}$ g/mol	normal	$-130 \cdot 10^{-18}$	$-380 \cdot 10^{-24}$ mol/mol	0.0 %
M_{234U}	234.04095210 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-3.9 \cdot 10^{-12}$	$-7.9 \cdot 10^{-18}$ mol/mol	0.0 %
M_{235U}	235.043929900 g/mol	$200 \cdot 10^{-9}$ g/mol	normal	$-340 \cdot 10^{-12}$	$-68 \cdot 10^{-18}$ mol/mol	0.0 %
M_{236U}	236.04556800 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-3.2 \cdot 10^{-12}$	$-6.5 \cdot 10^{-18}$ mol/mol	0.0 %
M_{238U}	238.05078820 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$340 \cdot 10^{-12}$	$680 \cdot 10^{-18}$ mol/mol	0.0 %
m_{UEC101}	51.7754900 g	$45.0 \cdot 10^{-6}$ g	normal	$-1.7 \cdot 10^{-9}$	$-75 \cdot 10^{-15}$ mol/mol	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	$-86 \cdot 10^{-9}$	$-2.1 \cdot 10^{-12}$ mol/mol	0.0 %
$m_{UCRM116A}$	12.4082100 g	$35.0 \cdot 10^{-6}$ g	normal	$6.9 \cdot 10^{-9}$	$240 \cdot 10^{-15}$ mol/mol	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3 \cdot 10^{-6}$ g/g	normal	$86 \cdot 10^{-9}$	$5.0 \cdot 10^{-12}$ mol/mol	0.0 %
M_{Ua}	238.02889787 g/mol	$5.71 \cdot 10^{-6}$ g/mol				
f_{233Ua}	0.0 mol/mol	0.0 mol/mol				
f_{234Ua}	$55.077 \cdot 10^{-6}$ mol/mol	$109 \cdot 10^{-9}$ mol/mol				
f_{235Ua}	$7.20658 \cdot 10^{-3}$ mol/mol	$1.77 \cdot 10^{-6}$ mol/mol				
f_{236Ua}	$149.9 \cdot 10^{-9}$ mol/mol	$19.9 \cdot 10^{-9}$ mol/mol				
f_{238Ua}	0.99273819 mol/mol	$1.78 \cdot 10^{-6}$ mol/mol				
M_{Ub}	235.1857242 g/mol	$55.1 \cdot 10^{-6}$ g/mol				
f_{233Ub}	$360.24 \cdot 10^{-9}$ mol/mol	$2.43 \cdot 10^{-9}$ mol/mol				
f_{234Ub}	0.01080225 mol/mol	$4.48 \cdot 10^{-6}$ mol/mol				
f_{235Ub}	0.9325468 mol/mol	$18.6 \cdot 10^{-6}$ mol/mol				
f_{236Ub}	$8.83243 \cdot 10^{-3}$ mol/mol	$3.56 \cdot 10^{-6}$ mol/mol				

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
f_{238Ub}	0.0478182 mol/mol	$18.2 \cdot 10^{-6}$ mol/mol				
$n_{233,a}$	0.0 mol	0.0 mol				
$n_{238,a}$	0.21590570 mol	$5.42 \cdot 10^{-6}$ mol				
$n_{233,b}$	$18.996 \cdot 10^{-9}$ mol	$128 \cdot 10^{-12}$ mol				
$n_{238,b}$	$2.521462 \cdot 10^{-3}$ mol	$971 \cdot 10^{-9}$ mol				
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 mol/mol	0.0 %
$R_{234U/238Ua}$	$55.480 \cdot 10^{-6}$ mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	$84 \cdot 10^{-9}$	$9.2 \cdot 10^{-15}$ mol/mol	0.0 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	$84 \cdot 10^{-9}$	$150 \cdot 10^{-15}$ mol/mol	0.0 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	$85 \cdot 10^{-9}$	$1.7 \cdot 10^{-15}$ mol/mol	0.0 %
$R_{233U/235Ub}$	$386.30 \cdot 10^{-9}$ mol/mol	$2.61 \cdot 10^{-9}$ mol/mol	normal	0.23	$590 \cdot 10^{-12}$ mol/mol	100.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85 \cdot 10^{-6}$ mol/mol	normal	$-80 \cdot 10^{-9}$	$-390 \cdot 10^{-15}$ mol/mol	0.0 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5 \cdot 10^{-6}$ mol/mol	normal	$-100 \cdot 10^{-9}$	$-2.1 \cdot 10^{-12}$ mol/mol	0.0 %
$R_{236U/235Ub}$	$9.47130 \cdot 10^{-3}$ mol/mol	$3.85 \cdot 10^{-6}$ mol/mol	normal	$-80 \cdot 10^{-9}$	$-310 \cdot 10^{-15}$ mol/mol	0.0 %
ΣR_{Ua}	1.00731493 mol/mol	$1.80 \cdot 10^{-6}$ mol/mol				
ΣR_{Ub}	1.0723323 mol/mol	$21.4 \cdot 10^{-6}$ mol/mol				
$n_{233,c}$	0.0 mol	0.0 mol	normal	0.0	0.0 mol/mol	0.0 %
$n_{238,c}$	$12.320 \cdot 10^{-12}$ mol	$118 \cdot 10^{-15}$ mol		$-400 \cdot 10^{-9}$	$-47 \cdot 10^{-21}$ mol/mol	0.0 %
$R_{233U/238U}$	$86.966 \cdot 10^{-9}$ mol/mol	$587 \cdot 10^{-12}$ mol/mol				

$R_{234U/238U}$: $^{234}U/^{238}U$ amount ratio in IRMM-1027r

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
n_{234U}	$581.654 \cdot 10^{-6}$ mol	$240 \cdot 10^{-9}$ mol				
n_{238U}	0.21842716 mol	$5.50 \cdot 10^{-6}$ mol				
M_{233U}	233.03963520 g/mol	$2.90 \cdot 10^{-6}$ g/mol	normal	$-3.9 \cdot 10^{-12}$	$-11 \cdot 10^{-18}$ mol/mol	0.0 %
M_{234U}	234.04095210 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-120 \cdot 10^{-9}$	$-240 \cdot 10^{-15}$ mol/mol	0.0 %
M_{235U}	235.043929900 g/mol	$200 \cdot 10^{-9}$ g/mol	normal	$-10 \cdot 10^{-6}$	$-2.0 \cdot 10^{-12}$ mol/mol	0.0 %
M_{236U}	236.04556800 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-97 \cdot 10^{-9}$	$-190 \cdot 10^{-15}$ mol/mol	0.0 %
M_{238U}	238.05078820 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$10 \cdot 10^{-6}$	$20 \cdot 10^{-12}$ mol/mol	0.0 %
m_{UEC101}	51.7754900 g	$45.0 \cdot 10^{-6}$ g	normal	$-50 \cdot 10^{-6}$	$-2.2 \cdot 10^{-9}$ mol/mol	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	$-2.6 \cdot 10^{-3}$	$-64 \cdot 10^{-9}$ mol/mol	0.3 %
$m_{UCRM116A}$	12.4082100 g	$35.0 \cdot 10^{-6}$ g	normal	$210 \cdot 10^{-6}$	$7.3 \cdot 10^{-9}$ mol/mol	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3 \cdot 10^{-6}$ g/g	normal	$2.6 \cdot 10^{-3}$	$150 \cdot 10^{-9}$ mol/mol	1.9 %
M_{Ua}	238.02889787 g/mol	$5.71 \cdot 10^{-6}$ g/mol				
f_{233Ua}	0.0 mol/mol	0.0 mol/mol				
f_{234Ua}	$55.077 \cdot 10^{-6}$ mol/mol	$109 \cdot 10^{-9}$ mol/mol				
f_{235Ua}	$7.20658 \cdot 10^{-3}$ mol/mol	$1.77 \cdot 10^{-6}$ mol/mol				
f_{236Ua}	$149.9 \cdot 10^{-9}$ mol/mol	$19.9 \cdot 10^{-9}$ mol/mol				
f_{238Ua}	0.99273819 mol/mol	$1.78 \cdot 10^{-6}$ mol/mol				
M_{Ub}	235.1857242 g/mol	$55.1 \cdot 10^{-6}$ g/mol				
f_{233Ub}	$360.24 \cdot 10^{-9}$ mol/mol	$2.43 \cdot 10^{-9}$ mol/mol				
f_{234Ub}	0.01080225 mol/mol	$4.48 \cdot 10^{-6}$ mol/mol				
f_{235Ub}	0.9325468 mol/mol	$18.6 \cdot 10^{-6}$ mol/mol				
f_{236Ub}	$8.83243 \cdot 10^{-3}$ mol/mol	$3.56 \cdot 10^{-6}$ mol/mol				

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
f_{238Ub}	0.0478182 mol/mol	$18.2 \cdot 10^{-6}$ mol/mol				
$n_{234,a}$	$11.9784 \cdot 10^{-6}$ mol	$23.8 \cdot 10^{-9}$ mol				
$n_{238,a}$	0.21590570 mol	$5.42 \cdot 10^{-6}$ mol				
$n_{234,b}$	$569.605 \cdot 10^{-6}$ mol	$239 \cdot 10^{-9}$ mol				
$n_{238,b}$	$2.521462 \cdot 10^{-3}$ mol	$971 \cdot 10^{-9}$ mol				
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 mol/mol	0.0 %
$R_{234U/238Ua}$	$55.480 \cdot 10^{-6}$ mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	0.99	$110 \cdot 10^{-9}$ mol/mol	1.0 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	$2.5 \cdot 10^{-3}$	$4.5 \cdot 10^{-9}$ mol/mol	0.0 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	$2.5 \cdot 10^{-3}$	$51 \cdot 10^{-12}$ mol/mol	0.0 %
$R_{233U/235Ub}$	$386.30 \cdot 10^{-9}$ mol/mol	$2.61 \cdot 10^{-9}$ mol/mol	normal	$-2.4 \cdot 10^{-3}$	$-6.2 \cdot 10^{-12}$ mol/mol	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85 \cdot 10^{-6}$ mol/mol	normal	0.22	$1.1 \cdot 10^{-6}$ mol/mol	96.5 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5 \cdot 10^{-6}$ mol/mol	normal	$-3.0 \cdot 10^{-3}$	$-62 \cdot 10^{-9}$ mol/mol	0.3 %
$R_{236U/235Ub}$	$9.47130 \cdot 10^{-3}$ mol/mol	$3.85 \cdot 10^{-6}$ mol/mol	normal	$-2.4 \cdot 10^{-3}$	$-9.3 \cdot 10^{-9}$ mol/mol	0.0 %
ΣR_{Ua}	1.00731493 mol/mol	$1.80 \cdot 10^{-6}$ mol/mol				
ΣR_{Ub}	1.0723323 mol/mol	$21.4 \cdot 10^{-6}$ mol/mol				
$n_{234,c}$	$71.527 \cdot 10^{-9}$ mol	$103 \cdot 10^{-12}$ mol		4.6	$470 \cdot 10^{-12}$ mol/mol	0.0 %
$n_{238,c}$	$12.320 \cdot 10^{-12}$ mol	$118 \cdot 10^{-15}$ mol		-0.012	$-1.4 \cdot 10^{-15}$ mol/mol	0.0 %
$R_{234U/238U}$	$2.66292 \cdot 10^{-3}$ mol/mol	$1.10 \cdot 10^{-6}$ mol/mol				

$R_{235U/238U}$: $^{235}U/^{238}U$ amount ratio in IRMM-1027r

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
n_{235U}	0.05074886 mol	$3.06 \cdot 10^{-6}$ mol				
n_{238U}	0.21842716 mol	$5.50 \cdot 10^{-6}$ mol				
M_{233U}	233.03963520 g/mol	$2.90 \cdot 10^{-6}$ g/mol	normal	$-340 \cdot 10^{-12}$	$-990 \cdot 10^{-18}$ mol/mol	0.0 %
M_{234U}	234.04095210 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-10 \cdot 10^{-6}$	$-20 \cdot 10^{-12}$ mol/mol	0.0 %
M_{235U}	235.043929900 g/mol	$200 \cdot 10^{-9}$ g/mol	normal	$-880 \cdot 10^{-6}$	$-180 \cdot 10^{-12}$ mol/mol	0.0 %
M_{236U}	236.04556800 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-8.4 \cdot 10^{-6}$	$-17 \cdot 10^{-12}$ mol/mol	0.0 %
M_{238U}	238.05078820 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$880 \cdot 10^{-6}$	$1.8 \cdot 10^{-9}$ mol/mol	0.0 %
m_{UEC101}	51.7754900 g	$45.0 \cdot 10^{-6}$ g	normal	$-4.3 \cdot 10^{-3}$	$-190 \cdot 10^{-9}$ mol/mol	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	-0.22	$-5.6 \cdot 10^{-6}$ mol/mol	13.2 %
$m_{UCRM116A}$	12.4082100 g	$35.0 \cdot 10^{-6}$ g	normal	0.018	$630 \cdot 10^{-9}$ mol/mol	0.2 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3 \cdot 10^{-6}$ g/g	normal	0.22	$13 \cdot 10^{-6}$ mol/mol	71.7 %
M_{Ua}	238.02889787 g/mol	$5.71 \cdot 10^{-6}$ g/mol				
f_{233Ua}	0.0 mol/mol	0.0 mol/mol				
f_{234Ua}	$55.077 \cdot 10^{-6}$ mol/mol	$109 \cdot 10^{-9}$ mol/mol				
f_{235Ua}	$7.20658 \cdot 10^{-3}$ mol/mol	$1.77 \cdot 10^{-6}$ mol/mol				
f_{236Ua}	$149.9 \cdot 10^{-9}$ mol/mol	$19.9 \cdot 10^{-9}$ mol/mol				
f_{238Ua}	0.99273819 mol/mol	$1.78 \cdot 10^{-6}$ mol/mol				
M_{Ub}	235.1857242 g/mol	$55.1 \cdot 10^{-6}$ g/mol				
f_{233Ub}	$360.24 \cdot 10^{-9}$ mol/mol	$2.43 \cdot 10^{-9}$ mol/mol				
f_{234Ub}	0.01080225 mol/mol	$4.48 \cdot 10^{-6}$ mol/mol				
f_{235Ub}	0.9325468 mol/mol	$18.6 \cdot 10^{-6}$ mol/mol				
f_{236Ub}	$8.83243 \cdot 10^{-3}$ mol/mol	$3.56 \cdot 10^{-6}$ mol/mol				

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
f_{238Ub}	0.0478182 mol/mol	$18.2 \cdot 10^{-6}$ mol/mol				
$n_{235,a}$	$1.567324 \cdot 10^{-3}$ mol	$388 \cdot 10^{-9}$ mol				
$n_{238,a}$	0.21590570 mol	$5.42 \cdot 10^{-6}$ mol				
$n_{235,b}$	0.04917336 mol	$3.04 \cdot 10^{-6}$ mol				
$n_{238,b}$	$2.521462 \cdot 10^{-3}$ mol	$971 \cdot 10^{-9}$ mol				
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 mol/mol	0.0 %
$R_{234U/238Ua}$	$55.480 \cdot 10^{-6}$ mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	0.22	$24 \cdot 10^{-9}$ mol/mol	0.0 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	1.2	$2.2 \cdot 10^{-6}$ mol/mol	2.0 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	0.22	$4.4 \cdot 10^{-9}$ mol/mol	0.0 %
$R_{233U/235Ub}$	$386.30 \cdot 10^{-9}$ mol/mol	$2.61 \cdot 10^{-9}$ mol/mol	normal	-0.21	$-540 \cdot 10^{-12}$ mol/mol	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85 \cdot 10^{-6}$ mol/mol	normal	-0.21	$-1.0 \cdot 10^{-6}$ mol/mol	0.4 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5 \cdot 10^{-6}$ mol/mol	normal	-0.26	$-5.4 \cdot 10^{-6}$ mol/mol	12.3 %
$R_{236U/235Ub}$	$9.47130 \cdot 10^{-3}$ mol/mol	$3.85 \cdot 10^{-6}$ mol/mol	normal	-0.21	$-800 \cdot 10^{-9}$ mol/mol	0.3 %
ΣR_{Ua}	1.00731493 mol/mol	$1.80 \cdot 10^{-6}$ mol/mol				
ΣR_{Ub}	1.0723323 mol/mol	$21.4 \cdot 10^{-6}$ mol/mol				
$n_{235,c}$	$8.18101 \cdot 10^{-6}$ mol	$3.11 \cdot 10^{-9}$ mol		4.6	$14 \cdot 10^{-9}$ mol/mol	0.0 %
$n_{238,c}$	$12.320 \cdot 10^{-12}$ mol	$118 \cdot 10^{-15}$ mol		-1.1	$-130 \cdot 10^{-15}$ mol/mol	0.0 %
$R_{235U/238U}$	0.2323377 mol/mol	$15.3 \cdot 10^{-6}$ mol/mol				

$R_{236U/238U}$: $^{236}U/^{238}U$ amount ratio in IRMM-1027r

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
n_{236U}	$466.443 \cdot 10^{-6}$ mol	$190 \cdot 10^{-9}$ mol				
n_{238U}	0.21842716 mol	$5.50 \cdot 10^{-6}$ mol				
M_{233U}	233.03963520 g/mol	$2.90 \cdot 10^{-6}$ g/mol	normal	$-3.2 \cdot 10^{-12}$	$-9.4 \cdot 10^{-18}$ mol/mol	0.0 %
M_{234U}	234.04095210 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-96 \cdot 10^{-9}$	$-190 \cdot 10^{-15}$ mol/mol	0.0 %
M_{235U}	235.043929900 g/mol	$200 \cdot 10^{-9}$ g/mol	normal	$-8.3 \cdot 10^{-6}$	$-1.7 \cdot 10^{-12}$ mol/mol	0.0 %
M_{236U}	236.04556800 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-79 \cdot 10^{-9}$	$-160 \cdot 10^{-15}$ mol/mol	0.0 %
M_{238U}	238.05078820 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$8.4 \cdot 10^{-6}$	$17 \cdot 10^{-12}$ mol/mol	0.0 %
m_{UEC101}	51.7754900 g	$45.0 \cdot 10^{-6}$ g	normal	$-41 \cdot 10^{-6}$	$-1.8 \cdot 10^{-9}$ mol/mol	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	$-2.1 \cdot 10^{-3}$	$-53 \cdot 10^{-9}$ mol/mol	0.4 %
$m_{UCRM116A}$	12.4082100 g	$35.0 \cdot 10^{-6}$ g	normal	$170 \cdot 10^{-6}$	$5.9 \cdot 10^{-9}$ mol/mol	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3 \cdot 10^{-6}$ g/g	normal	$2.1 \cdot 10^{-3}$	$120 \cdot 10^{-9}$ mol/mol	2.0 %
M_{Ua}	238.02889787 g/mol	$5.71 \cdot 10^{-6}$ g/mol				
f_{233Ua}	0.0 mol/mol	0.0 mol/mol				
f_{234Ua}	$55.077 \cdot 10^{-6}$ mol/mol	$109 \cdot 10^{-9}$ mol/mol				
f_{235Ua}	$7.20658 \cdot 10^{-3}$ mol/mol	$1.77 \cdot 10^{-6}$ mol/mol				
f_{236Ua}	$149.9 \cdot 10^{-9}$ mol/mol	$19.9 \cdot 10^{-9}$ mol/mol				
f_{238Ua}	0.99273819 mol/mol	$1.78 \cdot 10^{-6}$ mol/mol				
M_{Ub}	235.1857242 g/mol	$55.1 \cdot 10^{-6}$ g/mol				
f_{233Ub}	$360.24 \cdot 10^{-9}$ mol/mol	$2.43 \cdot 10^{-9}$ mol/mol				
f_{234Ub}	0.01080225 mol/mol	$4.48 \cdot 10^{-6}$ mol/mol				
f_{235Ub}	0.9325468 mol/mol	$18.6 \cdot 10^{-6}$ mol/mol				
f_{236Ub}	$8.83243 \cdot 10^{-3}$ mol/mol	$3.56 \cdot 10^{-6}$ mol/mol				

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
f_{238Ub}	0.0478182 mol/mol	$18.2 \cdot 10^{-6}$ mol/mol				
$n_{236,a}$	$32.60 \cdot 10^{-9}$ mol	$4.32 \cdot 10^{-9}$ mol				
$n_{238,a}$	0.21590570 mol	$5.42 \cdot 10^{-6}$ mol				
$n_{236,b}$	$465.736 \cdot 10^{-6}$ mol	$190 \cdot 10^{-9}$ mol				
$n_{238,b}$	$2.521462 \cdot 10^{-3}$ mol	$971 \cdot 10^{-9}$ mol				
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 mol/mol	0.0 %
$R_{234U/238Ua}$	$55.480 \cdot 10^{-6}$ mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	$2.1 \cdot 10^{-3}$	$230 \cdot 10^{-12}$ mol/mol	0.0 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	$2.1 \cdot 10^{-3}$	$3.7 \cdot 10^{-9}$ mol/mol	0.0 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	0.99	$20 \cdot 10^{-9}$ mol/mol	0.0 %
$R_{233U/235Ub}$	$386.30 \cdot 10^{-9}$ mol/mol	$2.61 \cdot 10^{-9}$ mol/mol	normal	$-1.9 \cdot 10^{-3}$	$-5.1 \cdot 10^{-12}$ mol/mol	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85 \cdot 10^{-6}$ mol/mol	normal	$-2.0 \cdot 10^{-3}$	$-9.5 \cdot 10^{-9}$ mol/mol	0.0 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5 \cdot 10^{-6}$ mol/mol	normal	$-2.5 \cdot 10^{-3}$	$-51 \cdot 10^{-9}$ mol/mol	0.3 %
$R_{236U/235Ub}$	$9.47130 \cdot 10^{-3}$ mol/mol	$3.85 \cdot 10^{-6}$ mol/mol	normal	0.22	$860 \cdot 10^{-9}$ mol/mol	97.2 %
ΣR_{Ua}	1.00731493 mol/mol	$1.80 \cdot 10^{-6}$ mol/mol				
ΣR_{Ub}	1.0723323 mol/mol	$21.4 \cdot 10^{-6}$ mol/mol				
$n_{236,c}$	$675.004 \cdot 10^{-9}$ mol	$342 \cdot 10^{-12}$ mol		4.6	$1.6 \cdot 10^{-9}$ mol/mol	0.0 %
$n_{238,c}$	$12.320 \cdot 10^{-12}$ mol	$118 \cdot 10^{-15}$ mol		$-9.8 \cdot 10^{-3}$	$-1.1 \cdot 10^{-15}$ mol/mol	0.0 %
$R_{236U/238U}$	$2.135463 \cdot 10^{-3}$ mol/mol	$871 \cdot 10^{-9}$ mol/mol				

$m_{235Uvial80}$: **mass of ^{235}U in vial No 80**

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$\gamma_{Umixture}$	0.021351827 g/g	$502 \cdot 10^{-9}$ g/g				
M_U	237.4739989 g/mol	$30.7 \cdot 10^{-6}$ g/mol				
f_{233U}	$70.296 \cdot 10^{-9}$ mol/mol	$474 \cdot 10^{-12}$ mol/mol				
f_{234U}	$2.152489 \cdot 10^{-3}$ mol/mol	$885 \cdot 10^{-9}$ mol/mol				
f_{235U}	0.1878028 mol/mol	$10.0 \cdot 10^{-6}$ mol/mol				
f_{236U}	$1.726135 \cdot 10^{-3}$ mol/mol	$701 \cdot 10^{-9}$ mol/mol				
f_{238U}	0.8083185 mol/mol	$10.2 \cdot 10^{-6}$ mol/mol				
w_{235U}	0.18588106 g/g	$9.96 \cdot 10^{-6}$ g/g				
n_{233U}	$18.996 \cdot 10^{-9}$ mol	$128 \cdot 10^{-12}$ mol				
n_{234U}	$581.654 \cdot 10^{-6}$ mol	$240 \cdot 10^{-9}$ mol				
n_{235U}	0.05074886 mol	$3.06 \cdot 10^{-6}$ mol				
n_{236U}	$466.443 \cdot 10^{-6}$ mol	$190 \cdot 10^{-9}$ mol				
n_{238U}	0.21842716 mol	$5.50 \cdot 10^{-6}$ mol				
M_{233U}	233.03963520 g/mol	$2.90 \cdot 10^{-6}$ g/mol	normal	$-15 \cdot 10^{-12}$	$-43 \cdot 10^{-18}$ g	0.0 %
M_{234U}	234.04095210 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-440 \cdot 10^{-9}$	$-880 \cdot 10^{-15}$ g	0.0 %
M_{235U}	235.043929900 g/mol	$200 \cdot 10^{-9}$ g/mol	normal	$4.1 \cdot 10^{-6}$	$820 \cdot 10^{-15}$ g	0.0 %
M_{236U}	236.04556800 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-360 \cdot 10^{-9}$	$-720 \cdot 10^{-15}$ g	0.0 %
M_{238U}	238.05078820 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-3.2 \cdot 10^{-6}$	$-6.5 \cdot 10^{-12}$ g	0.0 %
$m_{solution1027r}$	3005.4200 g	0.0125 g	normal	$-3.3 \cdot 10^{-6}$	$-41 \cdot 10^{-9}$ g	0.0 %
m_{UEC101}	51.7754900 g	$45.0 \cdot 10^{-6}$ g	normal	$5.9 \cdot 10^{-6}$	$270 \cdot 10^{-12}$ g	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	$310 \cdot 10^{-6}$	$7.7 \cdot 10^{-9}$ g	0.0 %
$m_{UCRM116A}$	12.4082100 g	$35.0 \cdot 10^{-6}$ g	normal	$780 \cdot 10^{-6}$	$27 \cdot 10^{-9}$ g	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3 \cdot 10^{-6}$ g/g	normal	$9.6 \cdot 10^{-3}$	$560 \cdot 10^{-9}$ g	17.7 %
M_{Ua}	238.02889787 g/mol	$5.71 \cdot 10^{-6}$ g/mol				
f_{233Ua}	0.0 mol/mol	0.0 mol/mol				
f_{234Ua}	$55.077 \cdot 10^{-6}$ mol/mol	$109 \cdot 10^{-9}$ mol/mol				

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
f_{235Ua}	$7.20658 \cdot 10^{-3}$ mol/mol	$1.77 \cdot 10^{-6}$ mol/mol				
f_{236Ua}	$149.9 \cdot 10^{-9}$ mol/mol	$19.9 \cdot 10^{-9}$ mol/mol				
f_{238Ua}	0.99273819 mol/mol	$1.78 \cdot 10^{-6}$ mol/mol				
M_{Ub}	235.1857242 g/mol	$55.1 \cdot 10^{-6}$ g/mol				
f_{233Ub}	$360.24 \cdot 10^{-9}$ mol/mol	$2.43 \cdot 10^{-9}$ mol/mol				
f_{234Ub}	0.01080225 mol/mol	$4.48 \cdot 10^{-6}$ mol/mol				
f_{235Ub}	0.9325468 mol/mol	$18.6 \cdot 10^{-6}$ mol/mol				
f_{236Ub}	$8.83243 \cdot 10^{-3}$ mol/mol	$3.56 \cdot 10^{-6}$ mol/mol				
f_{238Ub}	0.0478182 mol/mol	$18.2 \cdot 10^{-6}$ mol/mol				
$n_{233,a}$	0.0 mol	0.0 mol				
$n_{234,a}$	$11.9784 \cdot 10^{-6}$ mol	$23.8 \cdot 10^{-9}$ mol				
$n_{235,a}$	$1.567324 \cdot 10^{-3}$ mol	$388 \cdot 10^{-9}$ mol				
$n_{236,a}$	$32.60 \cdot 10^{-9}$ mol	$4.32 \cdot 10^{-9}$ mol				
$n_{238,a}$	0.21590570 mol	$5.42 \cdot 10^{-6}$ mol				
$n_{233,b}$	$18.996 \cdot 10^{-9}$ mol	$128 \cdot 10^{-12}$ mol				
$n_{234,b}$	$569.605 \cdot 10^{-6}$ mol	$239 \cdot 10^{-9}$ mol				
$n_{235,b}$	0.04917336 mol	$3.04 \cdot 10^{-6}$ mol				
$n_{236,b}$	$465.736 \cdot 10^{-6}$ mol	$190 \cdot 10^{-9}$ mol				
$n_{238,b}$	$2.521462 \cdot 10^{-3}$ mol	$971 \cdot 10^{-9}$ mol				
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 g	0.0 %
$R_{234U/238Ua}$	$55.480 \cdot 10^{-6}$ mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	$-300 \cdot 10^{-6}$	$-33 \cdot 10^{-12}$ g	0.0 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	0.042	$75 \cdot 10^{-9}$ g	0.3 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	$-300 \cdot 10^{-6}$	$-6.0 \cdot 10^{-12}$ g	0.0 %
$R_{233U/235Ub}$	$386.30 \cdot 10^{-9}$ mol/mol	$2.61 \cdot 10^{-9}$ mol/mol	normal	$-8.9 \cdot 10^{-3}$	$-23 \cdot 10^{-12}$ g	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85 \cdot 10^{-6}$ mol/mol	normal	$-8.9 \cdot 10^{-3}$	$-43 \cdot 10^{-9}$ g	0.1 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5 \cdot 10^{-6}$ mol/mol	normal	$-9.1 \cdot 10^{-3}$	$-190 \cdot 10^{-9}$ g	1.9 %

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$R_{236U/235Ub}$	$9.47130 \cdot 10^{-3}$ mol/mol	$3.85 \cdot 10^{-6}$ mol/mol	normal	$-9.0 \cdot 10^{-3}$	$-35 \cdot 10^{-9}$ g	0.0 %
ΣR_U	1.2371362 mol/mol	$15.6 \cdot 10^{-6}$ mol/mol				
ΣR_{Ua}	1.00731493 mol/mol	$1.80 \cdot 10^{-6}$ mol/mol				
ΣR_{Ub}	1.0723323 mol/mol	$21.4 \cdot 10^{-6}$ mol/mol				
$n_{234,c}$	$71.527 \cdot 10^{-9}$ mol	$103 \cdot 10^{-12}$ mol		-0.036	$-3.7 \cdot 10^{-12}$ g	0.0 %
$n_{235,c}$	$8.18101 \cdot 10^{-6}$ mol	$3.11 \cdot 10^{-9}$ mol		0.16	$500 \cdot 10^{-12}$ g	0.0 %
$n_{236,c}$	$675.004 \cdot 10^{-9}$ mol	$342 \cdot 10^{-12}$ mol		-0.037	$-12 \cdot 10^{-12}$ g	0.0 %
$n_{233,c}$	0.0 mol	0.0 mol	normal	0.0	0.0 g	0.0 %
$n_{238,c}$	$12.320 \cdot 10^{-12}$ mol	$118 \cdot 10^{-15}$ mol		-0.037	$-4.3 \cdot 10^{-15}$ g	0.0 %
m_{UMP2}	$2.098971 \cdot 10^{-3}$ g	$797 \cdot 10^{-9}$ g		$150 \cdot 10^{-6}$	$120 \cdot 10^{-12}$ g	0.0 %
$m_{aliquot80}$	2.500578 g	$300 \cdot 10^{-6}$ g	normal	$4.0 \cdot 10^{-3}$	$1.2 \cdot 10^{-6}$ g	79.7 %
$m_{235Uvial80}$	$9.92455 \cdot 10^{-3}$ g	$1.33 \cdot 10^{-6}$ g				

$m_{238Uvial80}$: **mass of ^{238}U in vial No 80**

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$\gamma_{Umixture}$	0.021351827 g/g	$502 \cdot 10^{-9}$ g/g				
M_U	237.4739989 g/mol	$30.7 \cdot 10^{-6}$ g/mol				
f_{233U}	$70.296 \cdot 10^{-9}$ mol/mol	$474 \cdot 10^{-12}$ mol/mol				
f_{234U}	$2.152489 \cdot 10^{-3}$ mol/mol	$885 \cdot 10^{-9}$ mol/mol				
f_{235U}	0.1878028 mol/mol	$10.0 \cdot 10^{-6}$ mol/mol				
f_{236U}	$1.726135 \cdot 10^{-3}$ mol/mol	$701 \cdot 10^{-9}$ mol/mol				
f_{238U}	0.8083185 mol/mol	$10.2 \cdot 10^{-6}$ mol/mol				
w_{238U}	0.8102817 g/g	$10.1 \cdot 10^{-6}$ g/g				
n_{233U}	$18.996 \cdot 10^{-9}$ mol	$128 \cdot 10^{-12}$ mol				
n_{234U}	$581.654 \cdot 10^{-6}$ mol	$240 \cdot 10^{-9}$ mol				
n_{235U}	0.05074886 mol	$3.06 \cdot 10^{-6}$ mol				
n_{236U}	$466.443 \cdot 10^{-6}$ mol	$190 \cdot 10^{-9}$ mol				
n_{238U}	0.21842716 mol	$5.50 \cdot 10^{-6}$ mol				
M_{233U}	233.03963520 g/mol	$2.90 \cdot 10^{-6}$ g/mol	normal	$-760 \cdot 10^{-15}$	$-2.2 \cdot 10^{-18}$ g	0.0 %
M_{234U}	234.04095210 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-33 \cdot 10^{-9}$	$-66 \cdot 10^{-15}$ g	0.0 %
M_{235U}	235.043929900 g/mol	$200 \cdot 10^{-9}$ g/mol	normal	$-3.3 \cdot 10^{-6}$	$-660 \cdot 10^{-15}$ g	0.0 %
M_{236U}	236.04556800 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$-19 \cdot 10^{-9}$	$-38 \cdot 10^{-15}$ g	0.0 %
M_{238U}	238.05078820 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$3.3 \cdot 10^{-6}$	$6.6 \cdot 10^{-12}$ g	0.0 %
$m_{solution1027r}$	3005.4200 g	0.0125 g	normal	$-14 \cdot 10^{-6}$	$-180 \cdot 10^{-9}$ g	0.1 %
m_{UEC101}	51.7754900 g	$45.0 \cdot 10^{-6}$ g	normal	$830 \cdot 10^{-6}$	$37 \cdot 10^{-9}$ g	0.0 %
$\eta_{purityEC101}$	0.9998500 g/g	$25.0 \cdot 10^{-6}$ g/g	normal	0.043	$1.1 \cdot 10^{-6}$ g	4.1 %
$m_{UCRM116A}$	12.4082100 g	$35.0 \cdot 10^{-6}$ g	normal	$40 \cdot 10^{-6}$	$1.4 \cdot 10^{-9}$ g	0.0 %
$\eta_{purityCRM116A}$	0.9994500 g/g	$58.3 \cdot 10^{-6}$ g/g	normal	$500 \cdot 10^{-6}$	$29 \cdot 10^{-9}$ g	0.0 %
M_{Ua}	238.02889787 g/mol	$5.71 \cdot 10^{-6}$ g/mol				
f_{233Ua}	0.0 mol/mol	0.0 mol/mol				
f_{234Ua}	$55.077 \cdot 10^{-6}$ mol/mol	$109 \cdot 10^{-9}$ mol/mol				

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
f_{235Ua}	$7.20658 \cdot 10^{-3}$ mol/mol	$1.77 \cdot 10^{-6}$ mol/mol				
f_{236Ua}	$149.9 \cdot 10^{-9}$ mol/mol	$19.9 \cdot 10^{-9}$ mol/mol				
f_{238Ua}	0.99273819 mol/mol	$1.78 \cdot 10^{-6}$ mol/mol				
M_{Ub}	235.1857242 g/mol	$55.1 \cdot 10^{-6}$ g/mol				
f_{233Ub}	$360.24 \cdot 10^{-9}$ mol/mol	$2.43 \cdot 10^{-9}$ mol/mol				
f_{234Ub}	0.01080225 mol/mol	$4.48 \cdot 10^{-6}$ mol/mol				
f_{235Ub}	0.9325468 mol/mol	$18.6 \cdot 10^{-6}$ mol/mol				
f_{236Ub}	$8.83243 \cdot 10^{-3}$ mol/mol	$3.56 \cdot 10^{-6}$ mol/mol				
f_{238Ub}	0.0478182 mol/mol	$18.2 \cdot 10^{-6}$ mol/mol				
$n_{233,a}$	0.0 mol	0.0 mol				
$n_{234,a}$	$11.9784 \cdot 10^{-6}$ mol	$23.8 \cdot 10^{-9}$ mol				
$n_{235,a}$	$1.567324 \cdot 10^{-3}$ mol	$388 \cdot 10^{-9}$ mol				
$n_{236,a}$	$32.60 \cdot 10^{-9}$ mol	$4.32 \cdot 10^{-9}$ mol				
$n_{238,a}$	0.21590570 mol	$5.42 \cdot 10^{-6}$ mol				
$n_{233,b}$	$18.996 \cdot 10^{-9}$ mol	$128 \cdot 10^{-12}$ mol				
$n_{234,b}$	$569.605 \cdot 10^{-6}$ mol	$239 \cdot 10^{-9}$ mol				
$n_{235,b}$	0.04917336 mol	$3.04 \cdot 10^{-6}$ mol				
$n_{236,b}$	$465.736 \cdot 10^{-6}$ mol	$190 \cdot 10^{-9}$ mol				
$n_{238,b}$	$2.521462 \cdot 10^{-3}$ mol	$971 \cdot 10^{-9}$ mol				
$R_{233U/238Ua}$	0.0 mol/mol	0.0 mol/mol	normal	0.0	0.0 g	0.0 %
$R_{234U/238Ua}$	$55.480 \cdot 10^{-6}$ mol/mol	$110 \cdot 10^{-9}$ mol/mol	normal	-0.042	$-4.6 \cdot 10^{-9}$ g	0.0 %
$R_{235U/238Ua}$	$7.25930 \cdot 10^{-3}$ mol/mol	$1.80 \cdot 10^{-6}$ mol/mol	normal	-0.042	$-75 \cdot 10^{-9}$ g	0.0 %
$R_{236U/238Ua}$	$151.0 \cdot 10^{-9}$ mol/mol	$20.0 \cdot 10^{-9}$ mol/mol	normal	-0.042	$-840 \cdot 10^{-12}$ g	0.0 %
$R_{233U/235Ub}$	$386.30 \cdot 10^{-9}$ mol/mol	$2.61 \cdot 10^{-9}$ mol/mol	normal	$-460 \cdot 10^{-6}$	$-1.2 \cdot 10^{-12}$ g	0.0 %
$R_{234U/235Ub}$	0.01158360 mol/mol	$4.85 \cdot 10^{-6}$ mol/mol	normal	$-460 \cdot 10^{-6}$	$-2.2 \cdot 10^{-9}$ g	0.0 %
$R_{238U/235Ub}$	0.0512770 mol/mol	$20.5 \cdot 10^{-6}$ mol/mol	normal	$9.3 \cdot 10^{-3}$	$190 \cdot 10^{-9}$ g	0.1 %

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$R_{236U/235Ub}$	$9.47130 \cdot 10^{-3}$ mol/mol	$3.85 \cdot 10^{-6}$ mol/mol	normal	$-470 \cdot 10^{-6}$	$-1.8 \cdot 10^{-9}$ g	0.0 %
ΣR_U	1.2371362 mol/mol	$15.6 \cdot 10^{-6}$ mol/mol				
ΣR_{Ua}	1.00731493 mol/mol	$1.80 \cdot 10^{-6}$ mol/mol				
ΣR_{Ub}	1.0723323 mol/mol	$21.4 \cdot 10^{-6}$ mol/mol				
$n_{234,c}$	$71.527 \cdot 10^{-9}$ mol	$103 \cdot 10^{-12}$ mol		-0.16	$-16 \cdot 10^{-12}$ g	0.0 %
$n_{235,c}$	$8.18101 \cdot 10^{-6}$ mol	$3.11 \cdot 10^{-9}$ mol		-0.16	$-490 \cdot 10^{-12}$ g	0.0 %
$n_{236,c}$	$675.004 \cdot 10^{-9}$ mol	$342 \cdot 10^{-12}$ mol		-0.16	$-54 \cdot 10^{-12}$ g	0.0 %
$n_{233,c}$	0.0 mol	0.0 mol	normal	0.0	0.0 g	0.0 %
$n_{238,c}$	$12.320 \cdot 10^{-12}$ mol	$118 \cdot 10^{-15}$ mol		0.038	$4.4 \cdot 10^{-15}$ g	0.0 %
m_{UMP2}	$2.098971 \cdot 10^{-3}$ g	$797 \cdot 10^{-9}$ g		$670 \cdot 10^{-6}$	$540 \cdot 10^{-12}$ g	0.0 %
$m_{aliquot80}$	2.500578 g	$300 \cdot 10^{-6}$ g	normal	0.017	$5.2 \cdot 10^{-6}$ g	95.7 %
$m_{238Uvial80}$	0.04326250 g	$5.31 \cdot 10^{-6}$ g				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
$\gamma_{Umixture}$	0.0213518 g/g	$1.0 \cdot 10^{-6}$ g/g	2.00	manual
$\gamma_{235Umixture}$	$3.96890 \cdot 10^{-3}$ g/g	$480 \cdot 10^{-9}$ g/g	2.00	manual
$\gamma_{238Umixture}$	0.01730100 g/g	$880 \cdot 10^{-9}$ g/g	2.00	manual
$c_{Umixture}$	$89.9123 \cdot 10^{-6}$ mol/g	$4.2 \cdot 10^{-9}$ mol/g	2.00	manual
$c_{235Umixture}$	$16.8858 \cdot 10^{-6}$ mol/g	$2.0 \cdot 10^{-9}$ mol/g	2.00	manual
$c_{238Umixture}$	$72.6778 \cdot 10^{-6}$ mol/g	$3.7 \cdot 10^{-9}$ mol/g	2.00	manual
M_U	237.473999 g/mol	$61 \cdot 10^{-6}$ g/mol	2.00	manual
$R_{233U/238U}$	$87.0 \cdot 10^{-9}$ mol/mol	$1.2 \cdot 10^{-9}$ mol/mol	2.00	manual
$R_{234U/238U}$	$2.6629 \cdot 10^{-3}$ mol/mol	$2.2 \cdot 10^{-6}$ mol/mol	2.00	manual
$R_{235U/238U}$	0.232338 mol/mol	$31 \cdot 10^{-6}$ mol/mol	2.00	manual
$R_{236U/238U}$	$2.1355 \cdot 10^{-3}$ mol/mol	$1.7 \cdot 10^{-6}$ mol/mol	2.00	manual
w_{233U}	$68.98 \cdot 10^{-9}$ g/g	$930 \cdot 10^{-12}$ g/g	2.00	manual
w_{234U}	$2.1214 \cdot 10^{-3}$ g/g	$1.7 \cdot 10^{-6}$ g/g	2.00	manual
w_{235U}	0.185881 g/g	$20 \cdot 10^{-6}$ g/g	2.00	manual
w_{236U}	$1.7158 \cdot 10^{-3}$ g/g	$1.4 \cdot 10^{-6}$ g/g	2.00	manual
w_{238U}	0.810282 g/g	$20 \cdot 10^{-6}$ g/g	2.00	manual
$m_{235Uvial80}$	$9.9245 \cdot 10^{-3}$ g	$2.7 \cdot 10^{-6}$ g	2.00	manual
$m_{238Uvial80}$	0.043262 g	$11 \cdot 10^{-6}$ g	2.00	manual

Annex 14: The weighing certificate of the metals and the mother solution for the preparation of IRMM-1027r

Certificate of weighing

Institute for Reference Materials and Measurements

E.3866 **Issued date**: 08 September 2015 **Page** 1 **of** 1

Applicant: R. Jakopič **Unit**: SN3S

Project: Production and certification of IRMM-1027r

Description: Preparation mother solution IRMM-1027r

Date of request: Pu MP2 30 March 2015
Natural U EC 101 30 March 2015
Enriched U CRM 116-A 30 March 2015

Weighing date: 05 May 2015, 09 and 29 June 2015

The reported results apply only to the objects / samples described in this certificate.

	Mass [g]	Uncertainty [g]
Mass of Pu metal (MP2)	2.21139	0.00013
Mass of enriched U metal (CRM 116-A)	12.40821	0.00007
Mass of natural U metal (EC 101)	51.77549	0.00009
Mass of IRMM-1027r mother solution	3005.42	0.025

Observations:
Masses were determined by substitution weighing on balances AT 261 and At 201 with IRMM inventory No 1999 00337 27 and 1996 00547 73 and balance PR 5002 with inventory No. 9800298.

Traceability:
The certified mass values are traceable to the International Kilogram Prototype via regular calibrations of the IRMM principal kilogram. The sets of working mass standards M 3 and M 10 were used as reference in the mass determination.

Uncertainty:
All reported uncertainties are expanded uncertainties $U = k \cdot u_c$ where u_c is the combined standard uncertainty calculated according to the ISO/IEC Guide to the expression of Uncertainty in Measurement. The coverage factor $k = 2$ corresponds to a coverage probability of about 95 %.

Rožle Jakopič — Nuclear Chemistry Laboratory responsible

Jeroen Bauwens — Analyst

Retieseweg, B-2440 Geel, Belgium; Tel.: +32-(0)14-571 211 • Fax: +32-(0)14-571 978•http://www.irmm.jrc.be

Annex 15: The weighing certificate of the blend mixtures for the characterisation of Pu by ID-TIMS using IRMM-046b

Certificate of weighing

Institute for Reference Materials and Measurements

Reg. No. E.3869 **Date of issue**: 13 November 2015 **Page** 1 **of** 1

Applicant: R. Jakopic **Project:** IRMM-1027q

Description: Verification of IRMM-1027r LSD vials using IRMM-046b

Request for analysis number: 3372 **Date of request**: 21 Oct 2015

Weighing date: 23 Oct 2015

The reported results apply only to the objects/samples described in this certificate.

Blend	IRMM-046b Mass [g]	Uncertainty [g]
IRMM-1027r-80/046b-17	2.51288	0.00012
IRMM-1027r-179/046b-18	2.50212	0.00016
IRMM-1027r-268/046b-18	2.50361	0.00017
IRMM-1027r-429/046b-18	2.51123	0.00016
IRMM-1027r-523/046b-19	3.00378	0.00012
IRMM-1027r-610/046b-19	3.04049	0.00011
IRMM-1027r-756/046b-19	3.01388	0.00010
IRMM-1027r-894/046b-20	3.00875	0.00011
IRMM-1027r-971/046b-20	3.01073	0.00011
IRMM-1027r-1085/046b-20	3.00936	0.00011

Observations:
Masses were determined by substitution weighing on balances AT 261 with IRMM inventory No. 1999 00337 27

Traceability:
The certified mass values are traceable to the International Kilogram Prototype via regular calibrations of the IRMM principal kilogram. The set of working mass standards M 3 was used as reference in the mass determination.

Uncertainty:
All reported uncertainties are expanded uncertainties $U = k \cdot u_c$ where u_c is the combined standard uncertainty calculated according to the ISO/IEC Guide to the expression of Uncertainty in Measurement. The coverage factor $k = 2$ corresponds to a coverage probability of about 95 %.

Rožle Jakopič
Nuclear Chemistry Laboratory Responsible

Carmel Hennessy
Analyst

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Annex 16: The internal test report for the selected units of IRMM-1027r

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

Institute for Reference Materials and Measurements (Geel)

INTERNAL TEST REPORT # 3372

Requested by: R. Jakopic, SN3S Unit

Samples

Sample ID	Applicant sample identification
23501	IRMM-1027r LSD Spikes

Date of receipt of samples: 01/11/2015

Condition of the samples: U and Pu nitrate solutions, Radioactive material. Chemical separation and purification of samples prior to isotopic measurements was done following working instructions WI-D-00352, WI-D-00353 and WI-D-00352

Sub-sample ID	Analyte	Result (± expanded uncertainty[1])	Unit	Method[2]
Date:	01/12/2015			
1027r-80	$n(^{242}Pu)/n(^{239}Pu)$	0.155807(59)	mol / mol	WI-D-00360
1027r-268	$n(^{242}Pu)/n(^{239}Pu)$	0.154314(56)	mol / mol	WI-D-00360
1027r-523	$n(^{242}Pu)/n(^{239}Pu)$	0.181161(58)	mol / mol	WI-D-00360
1027r-179	$n(^{242}Pu)/n(^{239}Pu)$	0.153622(66)	mol / mol	WI-D-00360
1027r-429	$n(^{242}Pu)/n(^{239}Pu)$	0.151539(44)	mol / mol	WI-D-00360
Date:	04/12/2015			
1027r-610	$n(^{242}Pu)/n(^{239}Pu)$	0.183782(59)	mol / mol	WI-D-00360
1027r-894	$n(^{242}Pu)/n(^{239}Pu)$	0.184989(69)	mol / mol	WI-D-00360
1027r-1085	$n(^{242}Pu)/n(^{239}Pu)$	0.185426(87)	mol / mol	WI-D-00360
1027r-756	$n(^{242}Pu)/n(^{239}Pu)$	0.185473(68)	mol / mol	WI-D-00360
1027r-971	$n(^{242}Pu)/n(^{239}Pu)$	0.181696(62)	mol / mol	WI-D-00360
Date:	09/11/2015			
1027r-80	$n(^{233}U)/n(^{235}U)$	0.24490(14)	mol / mol	WI-D-00348
1027r-80	$n(^{233}U)/n(^{238}U)$	0.056931(82)	mol / mol	WI-D-00348
1027r-268	$n(^{233}U)/n(^{235}U)$	0.242581(81)	mol / mol	WI-D-00348
1027r-268	$n(^{233}U)/n(^{238}U)$	0.056406(45)	mol / mol	WI-D-00348
1027r-523	$n(^{233}U)/n(^{235}U)$	0.28478(13)	mol / mol	WI-D-00348

1027r-523	$n(^{233}U)/n(^{238}U)$	0.066220(75)	mol / mol	WI-D-00348
1027r-179	$n(^{233}U)/n(^{235}U)$	0.24152(10)	mol / mol	WI-D-00348
1027r-179	$n(^{233}U)/n(^{238}U)$	0.056165(58)	mol / mol	WI-D-00348
1027r-429	$n(^{233}U)/n(^{235}U)$	0.238177(72)	mol / mol	WI-D-00348
1027r-429	$n(^{233}U)/n(^{238}U)$	0.055367(41)	mol / mol	WI-D-00348
Date:	19/11/2015			
1027r-610	$n(^{233}U)/n(^{235}U)$	0.28870(18)	mol / mol	WI-D-00348
1027r-610	$n(^{233}U)/n(^{238}U)$	0.067091(65)	mol / mol	WI-D-00348
1027r-894	$n(^{233}U)/n(^{235}U)$	0.290682(88)	mol / mol	WI-D-00348
1027r-894	$n(^{233}U)/n(^{238}U)$	0.067554(51)	mol / mol	WI-D-00348
1027r-1085	$n(^{233}U)/n(^{235}U)$	0.29143(16)	mol / mol	WI-D-00348
1027r-1085	$n(^{233}U)/n(^{238}U)$	0.067754(89)	mol / mol	WI-D-00348
1027r-756	$n(^{233}U)/n(^{235}U)$	0.29137(16)	mol / mol	WI-D-00348
1027r-756	$n(^{233}U)/n(^{238}U)$	0.067704(93)	mol / mol	WI-D-00348
1027r-971	$n(^{233}U)/n(^{235}U)$	0.285481(88)	mol / mol	WI-D-00348
1027r-971	$n(^{233}U)/n(^{238}U)$	0.066336(51)	mol / mol	WI-D-00348

Notes:

Notes (to be deleted if not applicable, also the logo!)		
	1	Uncertainties are given as *(e.g. expanded (k=2) uncertainties according to the ISO Guide to the Expression of Uncertainty (GUM), corresponding to an approximate 95% confidence interval)*

Files name(s) of raw data:

Results of mass spectrometric measurements for Pu are stored in:
"G:\JRC.D.4\Nuclear Safeguards\Nuclear\PUTON DATA - SHARED\IRMM LSD 1027r"
The relevant data files are:
"P151201 IRMM 1027r Pu IDMS vials A - with carburized filaments - F-D-0266 Revision 7.xls "
"P151203 IRMM 1027r Pu IDMS vials B - with carburized filaments - F-D-0266 Revision 7.xls "

Results of mass spectrometric measurements for U are stored in:
" G:\JRC.D.4\Nuclear Safeguards\Nuclear\TRITON DATA - SHARED\LSD 1027r"
The relevant data files are:
" T151106 1027r - U IDMS vials C - F-D-00265 Revision 7.xls"
" T151117 1027r - U IDMS vials D - F-D-00265 Revision 7.xls "

07/12/2015
Date

Signature
Analyst

Signature
Laboratory Responsible

Annex 17: Combined uncertainty budget (magazine A and B) for the characterisation of plutonium in IRMM-1027r by ID-TIMS (normalised values to November 1, 2015)

Combined values for the characterisation of Pu239 in 1027r with 046b spike normalised 1 Nov 2015

Author: Rozle Jakopic Elements: Pu

Date of reference: 1 November 2015

Isotope amount ratios Pu MP2 (1st January 2007) to 1st November 2015

Atomic mass: the 2003 atomic mass evaluation by G. Audi et al., 2003

input data from GUM files turret A and B:

magazine A (vials): 80, 268, 523, 179, 429

magazine B (vials): 610, 894, 1085, 756, 97

Model Equation:

{----------concentration calculations----------}

$f_{c239Pu}(c_x)=c_x$;

{turret A 1 Dec 2015}

$c_{239Pu1}=f_{c239Pu}(c_{x1})* e^{(-\lambda_{239}\cdot\Delta t_1)}$;

$c_{239Pu2}=f_{c239Pu}(c_{x2})* e^{(-\lambda_{239}\cdot\Delta t_1)}$;

$c_{239Pu3}=f_{c239Pu}(c_{x3})* e^{(-\lambda_{239}\cdot\Delta t_1)}$;

$c_{239Pu4}=f_{c239Pu}(c_{x4})* e^{(-\lambda_{239}\cdot\Delta t_1)}$;

$c_{239Pu5}=f_{c239Pu}(c_{x5})* e^{(-\lambda_{239}\cdot\Delta t_1)}$;

{turret B 4 Dec 2015}

$c_{239Pu6}=f_{c239Pu}(c_{x6})* e^{(-\lambda_{239}\cdot\Delta t_2)}$;

$c_{239Pu7}=f_{c239Pu}(c_{x7})* e^{(-\lambda_{239}\cdot\Delta t_2)}$;

$c_{239Pu8}=f_{c239Pu}(c_{x8})* e^{(-\lambda_{239}\cdot\Delta t_2)}$;

$c_{239Pu9}=f_{c239Pu}(c_{x9})* e^{(-\lambda_{239}\cdot\Delta t_2)}$;

$c_{239Pu10}=f_{c239Pu}(c_{x10})* e^{(-\lambda_{239}\cdot\Delta t_2)}$;

{----------concentration calculations----------}

$c_{239Pu}=(c_{239Pu1}+c_{239Pu2}+c_{239Pu3}+c_{239Pu4}+c_{239Pu5}+c_{239Pu6}+c_{239Pu7}+c_{239Pu8}+c_{239Pu9}+c_{239Pu10})*K_{spike}/10$;

$c_{Pu}=c_{239Pu}/fdnorm_{239}$;

$\gamma_{239Pu}=c_{239Pu}*M_{239Pu}$;

$\gamma_{Pu}=Mdnorm_{Pu}*c_{Pu}$;

$m_{239Puvial80}=\gamma_{239Pu}*m_{aliquot80}$;

{----------operator----------}

$\varepsilon_1 = c_{239Pu} - c_{239Pu1}$;

$\varepsilon_2 = c_{239Pu} - c_{239Pu2}$;

$\varepsilon_3 = c_{239Pu} - c_{239Pu3}$;

$\varepsilon_4 = c_{239Pu} - c_{239Pu4}$;

$\varepsilon_5 = c_{239Pu} - c_{239Pu5}$;

$\varepsilon_6 = c_{239Pu} - c_{239Pu6}$;

$\varepsilon_7 = c_{239Pu} - c_{239Pu7}$;

$\varepsilon_8 = c_{239Pu} - c_{239Pu8}$;

$\varepsilon_9 = c_{239Pu} - c_{239Pu9}$;

$\varepsilon_{10} = c_{239Pu} - c_{239Pu10}$;

{----------amount fractions MP2----------}

$f_{238} = R_{238/239}/\Sigma R_{Pu}$;

$f_{239} = 1/\Sigma R_{Pu}$;

$f_{240} = R_{240/239}/\Sigma R_{Pu}$;

$f_{241} = R_{241/239}/\Sigma R_{Pu}$;

$f_{242} = R_{242/239}/\Sigma R_{Pu}$;

$f_{244} = R_{244/239}/\Sigma R_{Pu}$;

$M_{Pu} = M_{238Pu} \cdot f_{238} + M_{239Pu} \cdot f_{239} + M_{240Pu} \cdot f_{240} + M_{241Pu} \cdot f_{241} + M_{242Pu} \cdot f_{242} + M_{244Pu} \cdot f_{244}$;

{----------sum of ratios MP2 ----------}

$\Sigma R_{Pu} = R_{238/239} + 1 + R_{240/239} + R_{241/239} + R_{242/239} + R_{244/239}$;

{----------decayed isotopic ratios in the sample----------}

$Rd_{238/239} = R_{238/239} \cdot (e^{(-\lambda_{238} \cdot \Delta t_{norm})}/e^{(-\lambda_{239} \cdot \Delta t_{norm})})$;

$Rd_{240/239} = R_{240/239} \cdot (e^{(-\lambda_{240} \cdot \Delta t_{norm})}/e^{(-\lambda_{239} \cdot \Delta t_{norm})})$;

$Rd_{241/239} = R_{241/239} \cdot (e^{(-\lambda_{241} \cdot \Delta t_{norm})}/e^{(-\lambda_{239} \cdot \Delta t_{norm})})$;

$Rd_{242/239} = R_{242/239} \cdot (e^{(-\lambda_{242} \cdot \Delta t_{norm})}/e^{(-\lambda_{239} \cdot \Delta t_{norm})})$;

$Rd_{244/239} = R_{244/239} \cdot (e^{(-\lambda_{244} \cdot \Delta t_{norm})}/e^{(-\lambda_{239} \cdot \Delta t_{norm})})$;

{----------normalised decayed amount fractions----------}

$fdnorm_{238} = Rd_{238/239}/\Sigma Rd_{Pu}$;

$fdnorm_{239} = 1/\Sigma Rd_{Pu}$;

$fdnorm_{240} = Rd_{240/239}/\Sigma Rd_{Pu}$;

$fdnorm_{241} = Rd_{241/239}/\Sigma Rd_{Pu}$;

$fdnorm_{242} = Rd_{242/239}/\Sigma Rd_{Pu}$;

$fdnorm_{244} = Rd_{244/239}/\Sigma Rd_{Pu}$;

{----------normalised decayed mass fractions----------}

$wdnorm_{238} = fdnorm_{238} \cdot M_{238Pu}/Mdnorm_{Pu}$;

$wdnorm_{239} = fdnorm_{239} \cdot M_{239Pu}/Mdnorm_{Pu}$;

$wdnorm_{240} = fdnorm_{240} \cdot M_{240Pu}/Mdnorm_{Pu}$;

$wdnorm_{241} = fdnorm_{241} \cdot M_{241Pu}/Mdnorm_{Pu}$;

$wdnorm_{242} = fdnorm_{242} \cdot M_{242Pu}/Mdnorm_{Pu}$;

$wdnorm_{244} = fdnorm_{244} \cdot M_{244Pu}/Mdnorm_{Pu}$;

$Mdnorm_{Pu} = M_{238Pu} \cdot fdnorm_{238} + M_{239Pu} \cdot fdnorm_{239} + M_{240Pu} \cdot fdnorm_{240} + M_{241Pu} \cdot fdnorm_{241} + M_{242Pu} \cdot fdnorm_{242} + M_{244Pu} \cdot fdnorm_{244}$;

$\Sigma Rd_{Pu} = Rd_{238/239} + 1 + Rd_{240/239} + Rd_{241/239} + Rd_{242/239} + Rd_{244/239}$;

$ln_2 = ln(2)$;

$\lambda_{238} = \ln_2 / \tau_{238}$;
$\lambda_{239} = \ln_2 / \tau_{239}$;
$\lambda_{240} = \ln_2 / \tau_{240}$;
$\lambda_{241} = \ln_2 / \tau_{241}$;
$\lambda_{242} = \ln_2 / \tau_{242}$;
$\lambda_{244} = \ln_2 / \tau_{244}$;

List of Quantities:

Quantity	Unit	Definition
γ_{239Pu}	g/g	
c_{239Pu}	mol/g	
Δt_{norm}	a	time difference Pu MP2 1 Jan 2007 and reference date 1 November 2015
Δt_1	a	time difference measurement date 1 Dec 2015 (IDMS) and reference date 1 November 2015
Δt_2	a	time difference measurement date 4 Sep 2015 (IDMS) and reference date 1 November 2015
c_{Pu}	mol/g	amount content of Pu in sample
γ_{Pu}	g/g	mass content of Pu in sample
$Mdnorm_{Pu}$	g/mol	molar mass of decayed Pu
$Rd_{238/239}$	mol/mol	isotope amount ratio n_{238}/n_{239} after decay to 1 November 2015
$Rd_{240/239}$	mol/mol	isotope amount ratio n_{240}/n_{239} after decay to 1 November 2015
$Rd_{241/239}$	mol/mol	isotope amount ratio n_{241}/n_{239} after decay to 1 November 2015
$Rd_{242/239}$	mol/mol	isotope amount ratio n_{242}/n_{239} after decay to 1 November 2015
$Rd_{244/239}$	mol/mol	isotope amount ratio n_{244}/n_{239} after decay to 1 November 2015
$fdnorm_{238}$		normalised decayed mole fraction of ^{238}Pu
$fdnorm_{239}$		normalised decayed mole fraction of ^{239}Pu
$fdnorm_{240}$		normalised decayed mole fraction of ^{240}Pu
$fdnorm_{241}$		normalised decayed mole fraction of ^{241}Pu
$fdnorm_{242}$		normalised decayed mole fraction of ^{242}Pu
$fdnorm_{244}$		normalised decayed mole fraction of ^{244}Pu
$wdnorm_{238}$		normalised decayed mass fraction of ^{238}Pu
$wdnorm_{239}$		normalised decayed mass fraction of ^{239}Pu
$wdnorm_{240}$		normalised decayed mass fraction of ^{240}Pu
$wdnorm_{241}$		normalised decayed mass fraction of ^{241}Pu
$wdnorm_{242}$		normalised decayed mass fraction of ^{242}Pu
$wdnorm_{244}$		normalised decayed mass fraction of ^{244}Pu
$R_{238/239}$	mol/mol	isotope amount ratio n_{238}/n_{239} of Pu MP2
$R_{240/239}$	mol/mol	isotope amount ratio n_{240}/n_{239} of Pu MP2
$R_{241/239}$	mol/mol	isotope amount ratio n_{241}/n_{239} of Pu MP2
$R_{242/239}$	mol/mol	isotope amount ratio n_{242}/n_{239} of Pu MP2

Quantity	Unit	Definition
$R_{244/239}$	mol/mol	isotope amount ratio n_{244}/n_{239} of Pu MP2
M_{Pu}	g/mol	molar mass of Pu at Pu MP2
f_{238}		mole fraction of ^{238}Pu
f_{239}		mole fraction of ^{239}Pu
f_{240}		mole fraction of ^{240}Pu
f_{241}		mole fraction of ^{241}Pu
f_{242}		mole fraction of ^{242}Pu
f_{244}		mole fraction of ^{244}Pu
e		
ln_2		
ΣR_{Pu}		
τ_{238}	a	half life ^{238}Pu
τ_{239}	a	half life ^{239}Pu
τ_{240}	a	half life ^{240}Pu
τ_{241}	a	half life ^{241}Pu
τ_{242}	a	half life ^{242}Pu
τ_{244}	a	half life ^{244}Pu
λ_{238}	a^{-1}	decay constant ^{238}Pu
λ_{239}	a^{-1}	decay constant ^{239}Pu
λ_{240}	a^{-1}	decay constant ^{240}Pu
λ_{241}	a^{-1}	decay constant ^{241}Pu
λ_{242}	a^{-1}	decay constant ^{242}Pu
λ_{244}	a^{-1}	decay constant ^{244}Pu
M_{238Pu}	g/mol	atomic mass for ^{238}Pu
M_{239Pu}	g/mol	atomic mass for ^{239}Pu
M_{240Pu}	g/mol	atomic mass for ^{240}Pu
M_{241Pu}	g/mol	atomic mass for ^{241}Pu
M_{242Pu}	g/mol	atomic mass for ^{242}Pu
M_{244Pu}	g/mol	atomic mass for ^{244}Pu
ΣRd_{Pu}		
c_{x1}	mol/g	import from respective GUMWB amount content of ^{239}Pu
c_{x2}	mol/g	import from respective GUMWB amount content of ^{239}Pu
c_{x3}	mol/g	import from respective GUMWB amount content of ^{239}Pu
c_{x4}	mol/g	import from respective GUMWB amount content of ^{239}Pu
c_{x5}	mol/g	import from respective GUMWB amount content of ^{239}Pu
c_{x6}	mol/g	import from respective GUMWB amount content of ^{239}Pu
c_{x7}	mol/g	import from respective GUMWB amount content of ^{239}Pu
c_{x8}	mol/g	import from respective GUMWB amount content of ^{239}Pu

Quantity	Unit	Definition
c_{x9}	mol/g	import from respective GUMWB amount content of ^{239}Pu
c_{x10}	mol/g	import from respective GUMWB amount content of ^{239}Pu
ε_1		
ε_2		
ε_3		
ε_4		
ε_5		
ε_6		
ε_7		
ε_8		
ε_9		
ε_{10}		
c_{239Pu1}	mol/g	normalised ^{239}Pu amount content in vial
c_{239Pu2}	mol/g	normalised ^{239}Pu amount content in vial
c_{239Pu3}	mol/g	normalised ^{239}Pu amount content in vial
c_{239Pu4}	mol/g	normalised ^{239}Pu amount content in vial
c_{239Pu5}	mol/g	normalised ^{239}Pu amount content in vial
c_{239Pu6}	mol/g	normalised ^{239}Pu amount content in vial
c_{239Pu7}	mol/g	normalised ^{239}Pu amount content in vial
c_{239Pu8}	mol/g	normalised ^{239}Pu amount content in vial
c_{239Pu9}	mol/g	normalised ^{239}Pu amount content in vial
$c_{239Pu10}$	mol/g	normalised ^{239}Pu amount content in vial
K_{spike}		relative expanded uncertainty of IRMM-046b spike
$m_{239Puvial80}$	g	mass of ^{239}Pu in vial No 80
$m_{aliquot80}$	g	mass of dispensed solution in vial No 80

Δt_{norm}: Constant
Value: 8.832307 a

01/01/2007, 01/11/2015, 3226 days/365.25=8.832307a

Δt_1: Constant
Value: -0.08124 a

01/12/2015, 01/11/2015,-30 days/365.25 =-0.08214

Δt_2: Constant
Value: -0.090349 a

04/12/2015, 1/11/2015, -33 days/365.25 = 0.090349 a

$R_{238/239}$: Type B normal distribution
Value: 0.00003083 mol/mol
Expanded Uncertainty: 0.00000029 mol/mol
Coverage Factor: 2

MP2 certificate

$R_{240/239}$:
Type B normal distribution
Value: 0.0224324 mol/mol
Expanded Uncertainty: 0.0000051 mol/mol
Coverage Factor: 2

MP2 certificate

$R_{241/239}$:
Type B normal distribution
Value: 0.0002378 mol/mol
Expanded Uncertainty: 0.0000031 mol/mol
Coverage Factor: 2

MP2 certificate

$R_{242/239}$:
Type B normal distribution
Value: 0.00007570 mol/mol
Expanded Uncertainty: 0.00000078 mol/mol
Coverage Factor: 2

MP2 certificate

$R_{244/239}$:
Type B normal distribution
Value: 0 mol/mol
Expanded Uncertainty: 0 mol/mol
Coverage Factor: 1

e:
Constant
Value: 2.7182818284590452536

τ_{238}:
Type B normal distribution
Value: 87.74 a
Expanded Uncertainty: 0.03 a
Coverage Factor: 1

τ_{239}:
Type B normal distribution
Value: 24100 a
Expanded Uncertainty: 11 a
Coverage Factor: 1

τ_{240}:
Type B normal distribution
Value: 6564 a
Expanded Uncertainty: 7 a
Coverage Factor: 1

τ_{241}:
Type B normal distribution
Value: 14.325 a
Expanded Uncertainty: 0.024 a
Coverage Factor: 2

τ_{242}:
Type B normal distribution
Value: 373000 a
Expanded Uncertainty: 3000 a
Coverage Factor: 1

τ_{244}:
Type B normal distribution
Value: $8 \cdot 10^7$ a
Expanded Uncertainty: $0.09 \cdot 10^7$ a
Coverage Factor: 1

M_{238Pu}:
Type B normal distribution
Value: 238.0495599 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al., 2003

M_{239Pu}:
Type B normal distribution
Value: 239.0521634 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al., 2003

M_{240Pu}:
Type B normal distribution
Value: 240.0538135 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al., 2003

M_{241Pu}:
Type B normal distribution
Value: 241.0568515 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al., 2003

M_{242Pu}:
Type B normal distribution
Value: 242.0587426 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al., 2003

M_{244Pu}:
Type B normal distribution
Value: 244.064204 g/mol
Expanded Uncertainty: 0.000010 g/mol
Coverage Factor: 2

G. Audi et al., 2003

c_{x1}:
Import
Filename: Verification 1027r IDMS Pu239 with 046b spike_vials_A_no_spike_Uc.smu
Symbol: c_{239Pu1}

c_{x2}:
Import
Filename: Verification 1027r IDMS Pu239 with 046b spike_vials_A_no_spike_Uc.smu
Symbol: c_{239Pu2}

464

c_{x3}:
Import
Filename: Verification 1027r IDMS Pu239 with 046b spike_vials_A_no_spike_Uc.smu
Symbol: c_{239Pu3}

299

c_{x4}: Import
Filename: Verification 1027r IDMS Pu239 with 046b spike_vials_A_no_spike_Uc.smu
Symbol: c_{239Pu4}

553

c_{x5}: Import
Filename: Verification 1027r IDMS Pu239 with 046b spike_vials_A_no_spike_Uc.smu
Symbol: c_{239Pu5}

206

c_{x6}: Import
Filename: Verification 1027r IDMS Pu239 with 046b spike_vials_B_no_spike_Uc.smu
Symbol: c_{239Pu1}

651

c_{x7}: Import
Filename: Verification 1027r IDMS Pu239 with 046b spike_vials_B_no_spike_Uc.smu
Symbol: c_{239Pu2}

943

c_{x8}: Import
Filename: Verification 1027r IDMS Pu239 with 046b spike_vials_B_no_spike_Uc.smu
Symbol: c_{239Pu3}

1140

c_{x9}: Import
Filename: Verification 1027r IDMS Pu239 with 046b spike_vials_B_no_spike_Uc.smu
Symbol: c_{239Pu4}

801

c_{x10}: Import
Filename: Verification 1027r IDMS Pu239 with 046b spike_vials_B_no_spike_Uc.smu
Symbol: c_{239Pu5}

1023

K_{spike}: Type B normal distribution
Value: 1
Expanded Uncertainty: $3.87063 \cdot 10^{-4}$
Coverage Factor: 2

relative expanded (k=2) uncertainty of the spike IRMM-046b

$m_{aliquot80}$: Type B normal distribution
Value: 2.5005784 g
Expanded Uncertainty: 0.0006000 g
Coverage Factor: 2

Input Correlation:

	c_{x2}	c_{x3}	c_{x4}	c_{x5}
c_{x2}	1	0.0015	0.0014	0.0019
c_{x3}	0.0015	1	0.0014	0.0018
c_{x4}	0.0014	0.0014	1	0.0017
c_{x5}	0.0019	0.0018	0.0017	1

	c_{x6}	c_{x7}	c_{x8}	c_{x9}	c_{x10}
c_{x6}	1	0.0013	0.0011	0.0013	0.0014
c_{x7}	0.0013	1	0.0009	0.0011	0.0012
c_{x8}	0.0011	0.0009	1	0.0010	0.0010
c_{x9}	0.0013	0.0011	0.0010	1	0.0012
c_{x10}	0.0014	0.0012	0.0010	0.0012	1

The abundance set for Pu is assumed as uncorrelated.

Interim Results:

Quantity	Value	Standard Uncertainty
$fdnorm_{238}$	$28.122 \cdot 10^{-6}$	$132 \cdot 10^{-9}$
$fdnorm_{239}$	0.97782604	$2.65 \cdot 10^{-6}$
$fdnorm_{240}$	0.02192010	$2.44 \cdot 10^{-6}$
$fdnorm_{241}$	$151.698 \cdot 10^{-6}$	$990 \cdot 10^{-9}$
$fdnorm_{242}$	$74.039 \cdot 10^{-6}$	$381 \cdot 10^{-9}$
M_{Pu}	239.07479084 g/mol	$4.49 \cdot 10^{-6}$ g/mol
f_{238}	$30.143 \cdot 10^{-6}$	$142 \cdot 10^{-9}$
f_{239}	0.97773050	$2.88 \cdot 10^{-6}$
f_{240}	0.02193284	$2.44 \cdot 10^{-6}$
f_{241}	$232.50 \cdot 10^{-6}$	$1.52 \cdot 10^{-6}$
f_{242}	$74.014 \cdot 10^{-6}$	$381 \cdot 10^{-9}$
ΣR_{Pu}	1.02277673	$3.01 \cdot 10^{-6}$
λ_{238}	$7.90001 \cdot 10^{-3}$ a^{-1}	$2.70 \cdot 10^{-6}$ a^{-1}
λ_{239}	$28.7613 \cdot 10^{-6}$ a^{-1}	$13.1 \cdot 10^{-9}$ a^{-1}
λ_{240}	$105.598 \cdot 10^{-6}$ a^{-1}	$113 \cdot 10^{-9}$ a^{-1}
λ_{241}	0.0483872 a^{-1}	$40.5 \cdot 10^{-6}$ a^{-1}
λ_{242}	$1.8583 \cdot 10^{-6}$ a^{-1}	$14.9 \cdot 10^{-9}$ a^{-1}
λ_{244}	$8.6643 \cdot 10^{-9}$ a^{-1}	$97.5 \cdot 10^{-12}$ a^{-1}
ΣRd_{Pu}	1.02267680	$2.77 \cdot 10^{-6}$
ε_1	$891 \cdot 10^{-12}$	$865 \cdot 10^{-12}$
ε_2	$-421 \cdot 10^{-12}$	$854 \cdot 10^{-12}$
ε_3	$-336 \cdot 10^{-12}$	$817 \cdot 10^{-12}$
ε_4	$729 \cdot 10^{-12}$	$907 \cdot 10^{-12}$
ε_5	$-275 \cdot 10^{-12}$	$799 \cdot 10^{-12}$
ε_6	$37 \cdot 10^{-12}$	$818 \cdot 10^{-12}$
ε_7	$-399 \cdot 10^{-12}$	$858 \cdot 10^{-12}$
ε_8	$-715 \cdot 10^{-12}$	$940 \cdot 10^{-12}$
ε_9	$74 \cdot 10^{-12}$	$853 \cdot 10^{-12}$
ε_{10}	$416 \cdot 10^{-12}$	$832 \cdot 10^{-12}$
c_{239Pu1}	$2.999755 \cdot 10^{-6}$ mol/g	$677 \cdot 10^{-12}$ mol/g
c_{239Pu2}	$3.001067 \cdot 10^{-6}$ mol/g	$661 \cdot 10^{-12}$ mol/g
c_{239Pu3}	$3.000982 \cdot 10^{-6}$ mol/g	$598 \cdot 10^{-12}$ mol/g
c_{239Pu4}	$2.999917 \cdot 10^{-6}$ mol/g	$744 \cdot 10^{-12}$ mol/g
c_{239Pu5}	$3.000921 \cdot 10^{-6}$ mol/g	$568 \cdot 10^{-12}$ mol/g
c_{239Pu6}	$3.000609 \cdot 10^{-6}$ mol/g	$600 \cdot 10^{-12}$ mol/g
c_{239Pu7}	$3.001044 \cdot 10^{-6}$ mol/g	$667 \cdot 10^{-12}$ mol/g

Quantity	Value	Standard Uncertainty
c_{239Pu8}	$3.001361 \cdot 10^{-6}$ mol/g	$793 \cdot 10^{-12}$ mol/g
c_{239Pu9}	$3.000572 \cdot 10^{-6}$ mol/g	$659 \cdot 10^{-12}$ mol/g
$c_{239Pu10}$	$3.000230 \cdot 10^{-6}$ mol/g	$624 \cdot 10^{-12}$ mol/g

Uncertainty Budgets:

γ_{239Pu}:

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
c_{239Pu}	$3.000646 \cdot 10^{-6}$ mol/g	$617 \cdot 10^{-12}$ mol/g				
Δt_1	-0.08124 a					
Δt_2	-0.090349 a					
e	2.718281828459					
$\ln_2$	0.69314718055995	0.0				
τ_{239}	24100.0 a	11.0 a	normal	$-73 \cdot 10^{-15}$	$-810 \cdot 10^{-15}$ g/g	0.0 %
λ_{239}	$28.7613 \cdot 10^{-6}$ a^{-1}	$13.1 \cdot 10^{-9}$ a^{-1}				
M_{239Pu}	239.05216340 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$3.0 \cdot 10^{-6}$	$6.0 \cdot 10^{-12}$ g/g	0.0 %
c_{x1}	$2.999748 \cdot 10^{-6}$ mol/g	$677 \cdot 10^{-12}$ mol/g		24	$16 \cdot 10^{-9}$ g/g	1.2 %
c_{x2}	$3.001060 \cdot 10^{-6}$ mol/g	$661 \cdot 10^{-12}$ mol/g		24	$16 \cdot 10^{-9}$ g/g	1.2 %
c_{x3}	$3.000975 \cdot 10^{-6}$ mol/g	$598 \cdot 10^{-12}$ mol/g		24	$14 \cdot 10^{-9}$ g/g	0.9 %
c_{x4}	$2.999910 \cdot 10^{-6}$ mol/g	$744 \cdot 10^{-12}$ mol/g		24	$18 \cdot 10^{-9}$ g/g	1.5 %
c_{x5}	$3.000914 \cdot 10^{-6}$ mol/g	$568 \cdot 10^{-12}$ mol/g		24	$14 \cdot 10^{-9}$ g/g	0.9 %
c_{x6}	$3.000601 \cdot 10^{-6}$ mol/g	$600 \cdot 10^{-12}$ mol/g		24	$14 \cdot 10^{-9}$ g/g	0.9 %
c_{x7}	$3.001036 \cdot 10^{-6}$ mol/g	$667 \cdot 10^{-12}$ mol/g		24	$16 \cdot 10^{-9}$ g/g	1.2 %
c_{x8}	$3.001353 \cdot 10^{-6}$ mol/g	$793 \cdot 10^{-12}$ mol/g		24	$19 \cdot 10^{-9}$ g/g	1.7 %
c_{x9}	$3.000564 \cdot 10^{-6}$ mol/g	$659 \cdot 10^{-12}$ mol/g		24	$16 \cdot 10^{-9}$ g/g	1.1 %
c_{x10}	$3.000222 \cdot 10^{-6}$ mol/g	$624 \cdot 10^{-12}$ mol/g		24	$15 \cdot 10^{-9}$ g/g	1.0 %
c_{239Pu1}	$2.999755 \cdot 10^{-6}$ mol/g	$677 \cdot 10^{-12}$ mol/g				
c_{239Pu2}	$3.001067 \cdot 10^{-6}$ mol/g	$661 \cdot 10^{-12}$ mol/g				
c_{239Pu3}	$3.000982 \cdot 10^{-6}$ mol/g	$598 \cdot 10^{-12}$ mol/g				
c_{239Pu4}	$2.999917 \cdot 10^{-6}$ mol/g	$744 \cdot 10^{-12}$ mol/g				
c_{239Pu5}	$3.000921 \cdot 10^{-6}$ mol/g	$568 \cdot 10^{-12}$ mol/g				

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
c_{239Pu6}	$3.000609 \cdot 10^{-6}$ mol/g	$600 \cdot 10^{-12}$ mol/g				
c_{239Pu7}	$3.001044 \cdot 10^{-6}$ mol/g	$667 \cdot 10^{-12}$ mol/g				
c_{239Pu8}	$3.001361 \cdot 10^{-6}$ mol/g	$793 \cdot 10^{-12}$ mol/g				
c_{239Pu9}	$3.000572 \cdot 10^{-6}$ mol/g	$659 \cdot 10^{-12}$ mol/g				
$c_{239Pu10}$	$3.000230 \cdot 10^{-6}$ mol/g	$624 \cdot 10^{-12}$ mol/g				
K_{spike}	1.000000	$194 \cdot 10^{-6}$	normal	$720 \cdot 10^{-6}$	$140 \cdot 10^{-9}$ g/g	88.5 %
γ_{239Pu}	$717.311 \cdot 10^{-6}$ g/g	$148 \cdot 10^{-9}$ g/g				

$Rd_{238/239}$: isotope amount ratio n_{238}/n_{239} after decay to 1 November 2015

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
Δt_{norm}	8.832307 a					
$R_{238/239}$	$30.830 \cdot 10^{-6}$ mol/mol	$145 \cdot 10^{-9}$ mol/mol	normal	0.93	$140 \cdot 10^{-9}$ mol/mol	100.0 %
e	2.718281828459					
ln_2	0.69314718055995	0.0				
τ_{238}	87.7400 a	0.0300 a	normal	$23 \cdot 10^{-9}$	$690 \cdot 10^{-12}$ mol/mol	0.0 %
τ_{239}	24100.0 a	11.0 a	normal	$-300 \cdot 10^{-15}$	$-3.3 \cdot 10^{-12}$ mol/mol	0.0 %
λ_{238}	$7.90001 \cdot 10^{-3}$ a^{-1}	$2.70 \cdot 10^{-6}$ a^{-1}				
λ_{239}	$28.7613 \cdot 10^{-6}$ a^{-1}	$13.1 \cdot 10^{-9}$ a^{-1}				
$Rd_{238/239}$	$28.759 \cdot 10^{-6}$ mol/mol	$135 \cdot 10^{-9}$ mol/mol				

$Rd_{240/239}$: isotope amount ratio n_{240}/n_{239} after decay to 1 November 2015

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
Δt_{norm}	8.832307 a					
$R_{240/239}$	0.02243240 mol/mol	$2.55 \cdot 10^{-6}$ mol/mol	normal	1.0	$2.5 \cdot 10^{-6}$ mol/mol	100.0 %
e	2.718281828459					
ln_2	0.69314718055995	0.0				
τ_{239}	24100.0 a	11.0 a	normal	$-240 \cdot 10^{-12}$	$-2.6 \cdot 10^{-9}$ mol/mol	0.0 %
τ_{240}	6564.00 a	7.00 a	normal	$3.2 \cdot 10^{-9}$	$22 \cdot 10^{-9}$ mol/mol	0.0 %
λ_{239}	$28.7613 \cdot 10^{-6}$ a^{-1}	$13.1 \cdot 10^{-9}$ a^{-1}				
λ_{240}	$105.598 \cdot 10^{-6}$ a^{-1}	$113 \cdot 10^{-9}$ a^{-1}				
$Rd_{240/239}$	0.02241718 mol/mol	$2.55 \cdot 10^{-6}$ mol/mol				

$Rd_{241/239}$: isotope amount ratio n_{241}/n_{239} after decay to 1 November 2015

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
Δt_{norm}	8.832307 a					
$R_{241/239}$	$237.80 \cdot 10^{-6}$ mol/mol	$1.55 \cdot 10^{-6}$ mol/mol	normal	0.65	$1.0 \cdot 10^{-6}$ mol/mol	99.7 %
e	2.718281828459					
ln_2	0.69314718055995	0.0				
τ_{239}	24100.0 a	11.0 a	normal	$-1.6 \cdot 10^{-12}$	$-18 \cdot 10^{-12}$ mol/mol	0.0 %
τ_{241}	14.3250 a	0.0120 a	normal	$4.6 \cdot 10^{-6}$	$56 \cdot 10^{-9}$ mol/mol	0.3 %
λ_{239}	$28.7613 \cdot 10^{-6}$ a^{-1}	$13.1 \cdot 10^{-9}$ a^{-1}				
λ_{241}	0.0483872 a^{-1}	$40.5 \cdot 10^{-6}$ a^{-1}				
$Rd_{241/239}$	$155.14 \cdot 10^{-6}$ mol/mol	$1.01 \cdot 10^{-6}$ mol/mol				

$Rd_{242/239}$: isotope amount ratio n_{242}/n_{239} after decay to 1 November 2015

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
Δt_{norm}	8.832307 a					
$R_{242/239}$	$75.700 \cdot 10^{-6}$ mol/mol	$390 \cdot 10^{-9}$ mol/mol	normal	1.0	$390 \cdot 10^{-9}$ mol/mol	100.0 %
e	2.718281828459					
ln_2	0.69314718055995	0.0				
τ_{239}	24100.0 a	11.0 a	normal	$-800 \cdot 10^{-15}$	$-8.8 \cdot 10^{-12}$ mol/mol	0.0 %
τ_{242}	$373.00 \cdot 10^{3}$ a	3000 a	normal	$3.3 \cdot 10^{-15}$	$10 \cdot 10^{-12}$ mol/mol	0.0 %
λ_{239}	$28.7613 \cdot 10^{-6}$ a^{-1}	$13.1 \cdot 10^{-9}$ a^{-1}				
λ_{242}	$1.8583 \cdot 10^{-6}$ a^{-1}	$14.9 \cdot 10^{-9}$ a^{-1}				
$Rd_{242/239}$	$75.718 \cdot 10^{-6}$ mol/mol	$390 \cdot 10^{-9}$ mol/mol				

$m_{239Puvial80}$: mass of ^{239}Pu in vial No 80

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
c_{239Pu}	$3.000646 \cdot 10^{-6}$ mol/g	$617 \cdot 10^{-12}$ mol/g				
Δt_1	-0.08124 a					
Δt_2	-0.090349 a					
e	2.718281828459					
$\ln_2$	0.69314718055995	0.0				
τ_{239}	24100.0 a	11.0 a	normal	$-180 \cdot 10^{-15}$	$-2.0 \cdot 10^{-12}$ g	0.0 %
λ_{239}	$28.7613 \cdot 10^{-6}$ a^{-1}	$13.1 \cdot 10^{-9}$ a^{-1}				
M_{239Pu}	239.05216340 g/mol	$2.00 \cdot 10^{-6}$ g/mol	normal	$7.5 \cdot 10^{-6}$	$15 \cdot 10^{-12}$ g	0.0 %
c_{x1}	$2.999748 \cdot 10^{-6}$ mol/g	$677 \cdot 10^{-12}$ mol/g		60	$40 \cdot 10^{-9}$ g	0.9 %
c_{x2}	$3.001060 \cdot 10^{-6}$ mol/g	$661 \cdot 10^{-12}$ mol/g		60	$39 \cdot 10^{-9}$ g	0.9 %
c_{x3}	$3.000975 \cdot 10^{-6}$ mol/g	$598 \cdot 10^{-12}$ mol/g		60	$36 \cdot 10^{-9}$ g	0.7 %
c_{x4}	$2.999910 \cdot 10^{-6}$ mol/g	$744 \cdot 10^{-12}$ mol/g		60	$44 \cdot 10^{-9}$ g	1.1 %
c_{x5}	$3.000914 \cdot 10^{-6}$ mol/g	$568 \cdot 10^{-12}$ mol/g		60	$34 \cdot 10^{-9}$ g	0.6 %
c_{x6}	$3.000601 \cdot 10^{-6}$ mol/g	$600 \cdot 10^{-12}$ mol/g		60	$36 \cdot 10^{-9}$ g	0.7 %
c_{x7}	$3.001036 \cdot 10^{-6}$ mol/g	$667 \cdot 10^{-12}$ mol/g		60	$40 \cdot 10^{-9}$ g	0.9 %
c_{x8}	$3.001353 \cdot 10^{-6}$ mol/g	$793 \cdot 10^{-12}$ mol/g		60	$47 \cdot 10^{-9}$ g	1.2 %
c_{x9}	$3.000564 \cdot 10^{-6}$ mol/g	$659 \cdot 10^{-12}$ mol/g		60	$39 \cdot 10^{-9}$ g	0.9 %
c_{x10}	$3.000222 \cdot 10^{-6}$ mol/g	$624 \cdot 10^{-12}$ mol/g		60	$37 \cdot 10^{-9}$ g	0.8 %
c_{239Pu1}	$2.999755 \cdot 10^{-6}$ mol/g	$677 \cdot 10^{-12}$ mol/g				
c_{239Pu2}	$3.001067 \cdot 10^{-6}$ mol/g	$661 \cdot 10^{-12}$ mol/g				
c_{239Pu3}	$3.000982 \cdot 10^{-6}$ mol/g	$598 \cdot 10^{-12}$ mol/g				
c_{239Pu4}	$2.999917 \cdot 10^{-6}$ mol/g	$744 \cdot 10^{-12}$ mol/g				
c_{239Pu5}	$3.000921 \cdot 10^{-6}$ mol/g	$568 \cdot 10^{-12}$ mol/g				
c_{239Pu6}	$3.000609 \cdot 10^{-6}$ mol/g	$600 \cdot 10^{-12}$ mol/g				

Combined values for the characterisation of Pu239 in 1027r with 046b spike normalised 1 Nov 2015

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
c_{239Pu7}	$3.001044 \cdot 10^{-6}$ mol/g	$667 \cdot 10^{-12}$ mol/g				
c_{239Pu8}	$3.001361 \cdot 10^{-6}$ mol/g	$793 \cdot 10^{-12}$ mol/g				
c_{239Pu9}	$3.000572 \cdot 10^{-6}$ mol/g	$659 \cdot 10^{-12}$ mol/g				
$c_{239Pu10}$	$3.000230 \cdot 10^{-6}$ mol/g	$624 \cdot 10^{-12}$ mol/g				
K_{spike}	1.000000	$194 \cdot 10^{-6}$	normal	$1.8 \cdot 10^{-3}$	$350 \cdot 10^{-9}$ g	66.0 %
$m_{aliquot80}$	2.500578 g	$300 \cdot 10^{-6}$ g	normal	$720 \cdot 10^{-6}$	$220 \cdot 10^{-9}$ g	25.4 %
$m_{239Puvial80}$	$1.793692 \cdot 10^{-3}$ g	$427 \cdot 10^{-9}$ g				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
γ_{239Pu}	$717.31 \cdot 10^{-6}$ g/g	$340 \cdot 10^{-9}$ g/g	2.30	manual
c_{239Pu}	$3.0006 \cdot 10^{-6}$ mol/g	$1.4 \cdot 10^{-9}$ mol/g	2.30	manual
c_{Pu}	$3.0687 \cdot 10^{-6}$ mol/g	$1.5 \cdot 10^{-9}$ mol/g	2.30	manual
γ_{Pu}	$733.65 \cdot 10^{-6}$ g/g	$350 \cdot 10^{-9}$ g/g	2.30	manual
$Mdnorm_{Pu}$	239.0746182 g/mol	$7.7 \cdot 10^{-6}$ g/mol	2.00	manual
$Rd_{238/239}$	$28.76 \cdot 10^{-6}$ mol/mol	$270 \cdot 10^{-9}$ mol/mol	2.00	manual
$Rd_{240/239}$	0.0224172 mol/mol	$5.1 \cdot 10^{-6}$ mol/mol	2.00	manual
$Rd_{241/239}$	$155.1 \cdot 10^{-6}$ mol/mol	$2.0 \cdot 10^{-6}$ mol/mol	2.00	manual
$Rd_{242/239}$	$75.72 \cdot 10^{-6}$ mol/mol	$780 \cdot 10^{-9}$ mol/mol	2.00	manual
$wdnorm_{238}$	$28.00 \cdot 10^{-6}$	$260 \cdot 10^{-9}$	2.00	manual
$wdnorm_{239}$	0.9777342	$5.3 \cdot 10^{-6}$	2.00	manual
$wdnorm_{240}$	0.0220099	$4.9 \cdot 10^{-6}$	2.00	manual
$wdnorm_{241}$	$153.0 \cdot 10^{-6}$	$2.0 \cdot 10^{-6}$	2.00	manual
$wdnorm_{242}$	$74.96 \cdot 10^{-6}$	$770 \cdot 10^{-9}$	2.00	manual
$m_{239Puvial80}$	$1.79369 \cdot 10^{-3}$ g	$980 \cdot 10^{-9}$ g	2.30	manual

Annex 18: Uncertainty budget for the characterisation of plutonium (turret A) of IRMM-1027r by ID-TIMS

Characterisation IRMM-1027r single vials IDMS Pu239 with 046b spike turret A

Author: Rozle Jakopic

Isotope amount ratios from MP2 certificate (IRMM, 01/01/2007) decayed to the date of IDMS measurement (1 Dec 2015)

mass spectrometry data: test report 3372 (IDMS), MP2 (1 Jan 2007)

Spike IRMM-046b

Date of measurement (IDMS): 1 Dec 2015

mass metrology certificates: dispensing (E3870), E3869 (blend mixtures)

IRMM-1027r vials (analytical sequence): 80, 268, 523, 179, 429

Model Equation:

$f_{c242Pu}(m_x,m_y,R_b)=c_{y.IRMM046bdec}*Rd_{239/242}*m_y/m_x *(R_{239/242Pu.IRMM046bdec}-(1/R_b)) / (1/R_b-Rd_{239/242})$;

$c_{239Pu1}=f_{c242Pu}(m_{x1},m_{y1},R_{b1})$;
$c_{239Pu2}=f_{c242Pu}(m_{x2},m_{y2},R_{b2})$;
$c_{239Pu3}=f_{c242Pu}(m_{x3},m_{y3},R_{b3})$;
$c_{239Pu4}=f_{c242Pu}(m_{x4},m_{y4},R_{b4})$;
$c_{239Pu5}=f_{c242Pu}(m_{x5},m_{y5},R_{b5})$;

{----------concentration calculations----------}

$c_{239Pu}=(c_{239Pu1}+c_{239Pu2}+c_{239Pu3}+c_{239Pu4}+c_{239Pu5})/5$;

$c_{Pu1}=c_{239Pu1}/fdnorm_{239}$;
$c_{Pu2}=c_{239Pu2}/fdnorm_{239}$;
$c_{Pu3}=c_{239Pu3}/fdnorm_{239}$;
$c_{Pu4}=c_{239Pu4}/fdnorm_{239}$;
$c_{Pu5}=c_{239Pu5}/fdnorm_{239}$;
$c_{Pu}=c_{239Pu}/fdnorm_{239}$;

$\gamma_{239Pu1}=c_{239Pu1}*M_{239Pu}$;
$\gamma_{239Pu2}=c_{239Pu2}*M_{239Pu}$;
$\gamma_{239Pu3}=c_{239Pu3}*M_{239Pu}$;
$\gamma_{239Pu4}=c_{239Pu4}*M_{239Pu}$;
$\gamma_{239Pu5}=c_{239Pu5}*M_{239Pu}$;
$\gamma_{239Pu}=c_{239Pu}*M_{239Pu}$;

$\gamma_{Pu1}=Mdnorm_{Pu}*c_{Pu1}$;
$\gamma_{Pu2}=Mdnorm_{Pu}*c_{Pu2}$;
$\gamma_{Pu3}=Mdnorm_{Pu}*c_{Pu3}$;
$\gamma_{Pu4}=Mdnorm_{Pu}*c_{Pu4}$;
$\gamma_{Pu5}=Mdnorm_{Pu}*c_{Pu5}$;
$\gamma_{Pu}=Mdnorm_{Pu}*c_{Pu}$;

{----------operator----------}

$\varepsilon_1 = c_{239Pu} - c_{239Pu1}$;

$\varepsilon_2 = c_{239Pu} - c_{239Pu2}$;

$\varepsilon_3 = c_{239Pu} - c_{239Pu3}$;

$\varepsilon_4 = c_{239Pu} - c_{239Pu4}$;

$\varepsilon_5 = c_{239Pu} - c_{239Pu5}$;

{----------amount fractions)----------}

$f_{238} = R_{238/239}/\Sigma R_{Pu}$;

$f_{239} = 1/\Sigma R_{Pu}$;

$f_{240} = R_{240/239}/\Sigma R_{Pu}$;

$f_{241} = R_{241/239}/\Sigma R_{Pu}$;

$f_{242} = R_{242/239}/\Sigma R_{Pu}$;

$f_{244} = R_{244/239}/\Sigma R_{Pu}$;

$M_{Pu} = M_{238Pu} \cdot f_{238} + M_{239Pu} \cdot f_{239} + M_{240Pu} \cdot f_{240} + M_{241Pu} \cdot f_{241} + M_{242Pu} \cdot f_{242} + M_{244Pu} \cdot f_{244}$;

{----------sum of ratios on ----------}

$\Sigma R_{Pu} = R_{238/239} + 1 + R_{240/239} + R_{241/239} + R_{242/239} + R_{244/239}$;

{----------decayed spike parameters----------}

$R_{239/242Pu.IRMM046bdec} = R_{239/242Pu.IRMM046b} * e^{(-\lambda_{239} \cdot \Delta t_{spike})}/(e^{(-\lambda_{242} \cdot \Delta t_{spike})})$;

$c_{y.IRMM046bdec} = c_{y.IRMM046b} * e^{(-\lambda_{242} \cdot \Delta t_{spike})}$;

{----------decayed isotopic ratios in the sample to 1 Dec 2015 (IDMS analysis)----------}

$Rd_{238/239} = R_{238/239} \cdot (e^{(-\lambda_{238} \cdot \Delta t_{norm})}/e^{(-\lambda_{239} \cdot \Delta t_{norm})})$;

$Rd_{240/239} = R_{240/239} \cdot (e^{(-\lambda_{240} \cdot \Delta t_{norm})}/e^{(-\lambda_{239} \cdot \Delta t_{norm})})$;

$Rd_{241/239} = R_{241/239} \cdot (e^{(-\lambda_{241} \cdot \Delta t_{norm})}/e^{(-\lambda_{239} \cdot \Delta t_{norm})})$;

$Rd_{242/239} = R_{242/239} \cdot (e^{(-\lambda_{242} \cdot \Delta t_{norm})}/e^{(-\lambda_{239} \cdot \Delta t_{norm})})$;

$Rd_{244/239} = R_{244/239} \cdot (e^{(-\lambda_{244} \cdot \Delta t_{norm})}/e^{(-\lambda_{239} \cdot \Delta t_{norm})})$;

$Rd_{239/242}=1/Rd_{242/239}$;

{----------normalised decayed amount fractions----------}

$fdnorm_{238} = Rd_{238/239}/\Sigma Rd_{Pu}$;

$fdnorm_{239} = 1/\Sigma Rd_{Pu}$;

$fdnorm_{240} = Rd_{240/239}/\Sigma Rd_{Pu}$;

$fdnorm_{241} = Rd_{241/239}/\Sigma Rd_{Pu}$;

$fdnorm_{242} = Rd_{242/239}/\Sigma Rd_{Pu}$;

$fdnorm_{244} = Rd_{244/239}/\Sigma Rd_{Pu}$;

{----------normalised decayed mass fractions----------}

$wdnorm_{238} = fdnorm_{238} \cdot M_{238Pu}/Mdnorm_{Pu}$;

$wdnorm_{239} = fdnorm_{239} \cdot M_{239Pu}/Mdnorm_{Pu}$;

$wdnorm_{240} = fdnorm_{240} \cdot M_{240Pu}/Mdnorm_{Pu}$;

$wdnorm_{241} = fdnorm_{241} \cdot M_{241Pu}/Mdnorm_{Pu}$;

$wdnorm_{242} = fdnorm_{242} \cdot M_{242Pu} / Mdnorm_{Pu}$;

$wdnorm_{244} = fdnorm_{244} \cdot M_{244Pu} / Mdnorm_{Pu}$;

$Mdnorm_{Pu} = M_{238Pu} \cdot fdnorm_{238} + M_{239Pu} \cdot fdnorm_{239} + M_{240Pu} \cdot fdnorm_{240} + M_{241Pu} \cdot fdnorm_{241} + M_{242Pu} \cdot fdnorm_{242} + M_{244Pu} \cdot fdnorm_{244}$;

$\Sigma Rd_{Pu} = Rd_{238/239} + 1 + Rd_{240/239} + Rd_{241/239} + Rd_{242/239} + Rd_{244/239}$;

$ln_2 = ln(2)$;

$\lambda_{238} = ln_2 / \tau_{238}$;

$\lambda_{239} = ln_2 / \tau_{239}$;

$\lambda_{240} = ln_2 / \tau_{240}$;

$\lambda_{241} = ln_2 / \tau_{241}$;

$\lambda_{242} = ln_2 / \tau_{242}$;

$\lambda_{244} = ln_2 / \tau_{244}$;

{----------metrological versus IDMS values 1 Dec 2015----------}

$\Delta_f = c_{239Pumixture} / c_{239Pu}$;

$diff_{Pu} = (c_{239Pu} - c_{239Pumixture}) / c_{239Pumixture} * 100$;

List of Quantities:

Quantity	Unit	Definition
c_{Pu}	mol/g	amount content of Pu in IRMM-1027r
c_{239Pu}	mol/g	amount content of ^{239}Pu in IRMM-1027r
γ_{239Pu}	g/g	mass content of ^{239}Pu in IRMM-1027r
γ_{Pu}	g/g	mass content of Pu in IRMM-1027r
Δt_{norm}	a	time difference MP2 and measurement Pu IDMS, 1 Dec 2015
$Mdnorm_{Pu}$	g/mol	molar mass of decayed Pu
$Rd_{238/239}$	mol/mol	isotope amount ratio n_{238}/n_{239} after decay, IRMM-1027r, 1 Dec 2015
$Rd_{240/239}$	mol/mol	isotope amount ratio n_{240}/n_{239} after decay, IRMM-1027r, 1 Dec 2015
$Rd_{241/239}$	mol/mol	isotope amount ratio n_{241}/n_{239} after decay, IRMM-1027r, 1 Dec 2015
$Rd_{242/239}$	mol/mol	isotope amount ratio n_{242}/n_{239} after decay, IRMM-1027r, 1 Dec 2015
$Rd_{244/239}$	mol/mol	isotope amount ratio n_{244}/n_{239} after decay, IRMM-1027r, 1 Dec 2015
$fdnorm_{238}$		normalised decayed mole fraction of ^{238}Pu , IRMM-1027r, 1 Dec 2015
$fdnorm_{239}$		normalised decayed mole fraction of ^{239}Pu , IRMM-1027r, 1 Dec 2015
$fdnorm_{240}$		normalised decayed mole fraction of ^{240}Pu, IRMM-1027r, 1 Dec 2015
$fdnorm_{241}$		normalised decayed mole fraction of ^{241}Pu, IRMM-1027r, 1 Dec 2015
$fdnorm_{242}$		normalised decayed mole fraction of ^{242}Pu, IRMM-1027r, 1 Dec 2015
$fdnorm_{244}$		normalised decayed mole fraction of ^{244}Pu, IRMM-1027r, 1 Dec 2015
$wdnorm_{238}$		normalised decayed mass fraction of ^{238}Pu, IRMM-1027r, 1 Dec 2015

Quantity	Unit	Definition
$wdnorm_{239}$		normalised decayed mass fraction of ^{239}Pu, IRMM-1027r, 1 Dec 2015
$wdnorm_{240}$		normalised decayed mass fraction of ^{240}Pu, IRMM-1027r, 1 Dec 2015
$wdnorm_{241}$		normalised decayed mass fraction of ^{241}Pu, IRMM-1027r, 1 Dec 2015
$wdnorm_{242}$		normalised decayed mass fraction of ^{242}Pu, IRMM-1027r, 1 Dec 2015
$wdnorm_{244}$		normalised decayed mass fraction of ^{244}Pu, IRMM-1027r, 1 Dec 2015
$R_{238/239}$	mol/mol	isotope amount ratio n_{239}/n_{239} of Pu in MP2
$R_{240/239}$	mol/mol	isotope amount ratio n_{240}/n_{239} of Pu in MP2
$R_{241/239}$	mol/mol	isotope amount ratio n_{241}/n_{239} of Pu in MP2
$R_{242/239}$	mol/mol	isotope amount ratio n_{242}/n_{239} of Pu in MP2
$R_{244/239}$	mol/mol	isotope amount ratio n_{244}/n_{239} of Pu in MP2
M_{Pu}	g/mol	molar mass of Pu
f_{238}		mole fraction of ^{238}Pu
f_{239}		mole fraction of ^{239}Pu
f_{240}		mole fraction of ^{240}Pu
f_{241}		mole fraction of ^{241}Pu
f_{242}		mole fraction of ^{242}Pu
f_{244}		mole fraction of ^{244}Pu
e		
ln_2		
ΣR_{Pu}		
τ_{238}	a	half life ^{238}Pu
τ_{239}	a	half life ^{239}Pu
τ_{240}	a	half life ^{240}Pu
τ_{241}	a	half life ^{241}Pu
τ_{242}	a	half life ^{242}Pu
τ_{244}	a	half life ^{244}Pu
λ_{238}	a^{-1}	decay constant ^{238}Pu
λ_{239}	a^{-1}	decay constant ^{239}Pu
λ_{240}	a^{-1}	decay constant ^{240}Pu
λ_{241}	a^{-1}	decay constant ^{241}Pu
λ_{242}	a^{-1}	decay constant ^{242}Pu
λ_{244}	a^{-1}	decay constant ^{244}Pu
M_{238Pu}	g/mol	atomic mass for ^{238}Pu
M_{239Pu}	g/mol	atomic mass for ^{239}Pu

Quantity	Unit	Definition
M_{240Pu}	g/mol	atomic mass for ^{240}Pu
M_{241Pu}	g/mol	atomic mass for ^{241}Pu
M_{242Pu}	g/mol	atomic mass for ^{242}Pu
M_{244Pu}	g/mol	atomic mass for ^{244}Pu
ΣRd_{Pu}		
$c_{y,IRMM046bdec}$	mol/g	decayed amount content of ^{242}Pu in IRMM-046b
$c_{y,IRMM046b}$	mol/g	amount content of ^{242}Pu in IRMM-046b
$R_{239/242Pu,IRMM046bdec}$	mol/mol	decayed isotope amount ratio n_{239}/n_{242} of Pu in IRMM-046b
$R_{239/242Pu,IRMM046b}$		isotope amount ratio n_{239}/n_{242} of Pu in IRMM-046b
$Rd_{239/242}$	mol/mol	isotope amount ratio n_{239}/n_{242} of Pu in MP2
Δt_{spike}	a	time difference certificate 046b (1 June 2010) and measurement date IRMM-1027r (1 Dec 2015)
c_{239Pu1}	mol/g	amount content of ^{239}Pu in vial 80
c_{239Pu2}	mol/g	amount content of ^{239}Pu in vial 268
c_{239Pu3}	mol/g	amount content of ^{239}Pu in vial 523
c_{239Pu4}	mol/g	amount content of ^{239}Pu in vial 179
c_{239Pu5}	mol/g	amount content of ^{239}Pu in vial 429
$c_{239Pumixture}$	mol/g	metrological (gravimetrical) amount content ^{239}Pu in IRMM-1027r
R_{b1}	mol/mol	measured $^{242}Pu/^{239}Pu$ ratio in blend 1, vial 80
R_{b2}	mol/mol	measured $^{242}Pu/^{239}Pu$ ratio in blend 2, vial 268
R_{b3}	mol/mol	measured $^{242}Pu/^{239}Pu$ ratio in blend 4, vial 523
R_{b4}	mol/mol	measured $^{242}Pu/^{239}Pu$ ratio in blend 4, vial 179
R_{b5}	mol/mol	measured $^{242}Pu/^{239}Pu$ ratio in blend 5, vial 429
m_{x1}	g	mass of sample 1027r in vial 80
m_{x2}	g	mass of sample 1027r in vial 268
m_{x3}	g	mass of sample 1027r in vial 523
m_{x4}	g	mass of sample 1027r in vial 179
m_{x5}	g	mass of sample 1027r in vial 429
m_{y1}	g	mass of spike in blend 1, vial 80
m_{y2}	g	mass of spike in blend 2, vial 268
m_{y3}	g	mass of spike in blend 3, vial 523
m_{y4}	g	mass of spike in blend 4, vial 179
m_{y5}	g	mass of spike in blend 5, vial 429
ε_1		
ε_2		
ε_3		
ε_4		
ε_5		

Quantity	Unit	Definition
c_{Pu1}	mol/g	Pu amount content in vial 80
c_{Pu2}	mol/g	Pu amount content in vial 268
c_{Pu3}	mol/g	Pu amount content in vial 523
c_{Pu4}	mol/g	Pu amount content in vial 179
c_{Pu5}	mol/g	Pu amount content in vial 429
γ_{Pu1}	g/g	Pu mass content in vial 80
γ_{Pu2}	g/g	Pu mass content in vial 268
γ_{Pu3}	g/g	Pu mass content in vial 523
γ_{Pu4}	g/g	Pu mass content in vial 179
γ_{Pu5}	g/g	Pu mass content in vial 429
γ_{239Pu1}	g/g	^{239}Pu mass content in vial 80
γ_{239Pu2}	g/g	^{239}Pu mass content in vial 268
γ_{239Pu3}	g/g	^{239}Pu mass content in vial 523
γ_{239Pu4}	g/g	^{239}Pu mass content in vial 179
γ_{239Pu5}	g/g	^{239}Pu mass content in vial 429
Δ_γ		
$diff_{Pu}$	%	relative difference (IDMS-metrological/metrological)

Δt_{norm}: Constant
Value: 8.914442 a

01/01/2007, 1/12/2015, delta t= 3256 days/365.25= 8.914442

$R_{238/239}$: Type B normal distribution
Value: 0.00003083 mol/mol
Expanded Uncertainty: 0.00000029 mol/mol
Coverage Factor: 2

MP2 certificate

$R_{240/239}$: Type B normal distribution
Value: 0.0224324 mol/mol
Expanded Uncertainty: 0.0000051 mol/mol
Coverage Factor: 2

MP2 certificate

$R_{241/239}$: Type B normal distribution
Value: 0.0002378 mol/mol
Expanded Uncertainty: 0.0000031 mol/mol
Coverage Factor: 2

MP2 certificate

$R_{242/239}$: Type B normal distribution
Value: 0.00007570 mol/mol
Expanded Uncertainty: 0.00000078 mol/mol
Coverage Factor: 2

MP2 certificate

$R_{244/239}$: Type B normal distribution
Value: 0 mol/mol
Expanded Uncertainty: 0 mol/mol
Coverage Factor: 1

MP2 certificate

e: Constant
Value: 2.7182818284590452536

τ_{238}: Type B normal distribution
Value: 87.74 a
Expanded Uncertainty: 0.03 a
Coverage Factor: 1

τ_{239}: Type B normal distribution
Value: 24100 a
Expanded Uncertainty: 11 a
Coverage Factor: 1

τ_{240}: Type B normal distribution
Value: 6561 a
Expanded Uncertainty: 7 a
Coverage Factor: 1

τ_{241}: Type B normal distribution
Value: 14.325 a
Expanded Uncertainty: 0.024 a
Coverage Factor: 2

τ_{242}: Type B normal distribution
Value: 373000 a
Expanded Uncertainty: 3000 a
Coverage Factor: 1

τ_{244}: Type B normal distribution
Value: $8 \cdot 10^7$ a
Expanded Uncertainty: $0.09 \cdot 10^7$ a
Coverage Factor: 1

M_{238Pu}: Type B normal distribution
Value: 238.0495599 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al, 2003

M_{239Pu}: Type B normal distribution
Value: 239.0521634 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al, 2003

M_{240Pu}: Type B normal distribution
Value: 240.0538135 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al, 2003

M_{241Pu}: Type B normal distribution
Value: 241.0568515 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al, 2003

M_{242Pu}: Type B normal distribution
Value: 242.0587426 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al, 2003

M_{244Pu}: Type B normal distribution
Value: 244.064204 g/mol
Expanded Uncertainty: 0.000010 g/mol
Coverage Factor: 2

G. Audi et al, 2003

$c_{y,IRMM046b}$: Type B normal distribution
Value: $4.6504 \cdot 10^{-7}$ mol/g
Expanded Uncertainty: $0.0018 \cdot 10^{-7}$ mol/g
Coverage Factor: 2

IRMM-046b certificate

$R_{239/242Pu,IRMM046b}$: Type B normal distribution
Value: 0.002212
Expanded Uncertainty: 0.000016
Coverage Factor: 2

IRMM-046b certificate

Δt_{spike}: Constant
Value: 5.500342 a

01/06/2010, 01/12/2015, delta t= 2009days/365.25=5.500342

$c_{239Pumixture}$: Import
Filename: ..\..\mother solution verification\IRMM-1027r Plutonium gravimetric mixture_1Dec_2015.smu
Symbol: $c_{Pumixture239}$

gravimetric mixture, decayed to 1 Dec 2015

R_{b1}: Type B normal distribution
Value: 0.155807 mol/mol
Expanded Uncertainty: 0.000059 mol/mol
Coverage Factor: 2

InternalTest Report 3372

R_{b2}:
Type B normal distribution
Value: 0.154314 mol/mol
Expanded Uncertainty: 0.000056 mol/mol
Coverage Factor: 2

InternalTest Report 3372

R_{b3}:
Type B normal distribution
Value: 0.181161 mol/mol
Expanded Uncertainty: 0.000058 mol/mol
Coverage Factor: 2

InternalTest Report 3372

R_{b4}:
Type B normal distribution
Value: 0.153622 mol/mol
Expanded Uncertainty: 0.000066 mol/mol
Coverage Factor: 2

InternalTest Report 3372

R_{b5}:
Type B normal distribution
Value: 0.151539 mol/mol
Expanded Uncertainty: 0.000044 mol/mol
Coverage Factor: 2

InternalTest Report 3372

m_{x1}:
Type B normal distribution
Value: 2.5006 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

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m_{x2}:
Type B normal distribution
Value: 2.5144 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

E3869

m_{x3}:
Type B normal distribution
Value: 2.5694 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

E3869

m_{x4}:
Type B normal distribution
Value: 2.5252 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

E3869

m_{x5}:
Type B normal distribution
Value: 2.5684 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

E3869

m_{y1}: Type B normal distribution
Value: 2.51288 g
Expanded Uncertainty: 0.00012 g
Coverage Factor: 2

E3869

m_{y2}: Type B normal distribution
Value: 2.50361 g
Expanded Uncertainty: 0.00017 g
Coverage Factor: 2

E3869

m_{y3}: Type B normal distribution
Value: 3.00378 g
Expanded Uncertainty: 0.00012 g
Coverage Factor: 2

E3869

m_{y4}: Type B normal distribution
Value: 2.50212 g
Expanded Uncertainty: 0.00016 g
Coverage Factor: 2

E3869

m_{y5}: Type B normal distribution
Value: 2.51123 g
Expanded Uncertainty: 0.00016 g
Coverage Factor: 2

E3869

Input Correlation:

The abundance set for Pu is assumed as uncorrelated.

Interim Results:

Quantity	Value	Standard Uncertainty
c_{Pu}	$3.068583 \cdot 10^{-6}$ mol/g	$665 \cdot 10^{-12}$ mol/g
c_{239Pu}	$3.000542 \cdot 10^{-6}$ mol/g	$650 \cdot 10^{-12}$ mol/g
γ_{239Pu}	$717.286 \cdot 10^{-6}$ g/g	$155 \cdot 10^{-9}$ g/g
γ_{Pu}	$733.620 \cdot 10^{-6}$ g/g	$159 \cdot 10^{-9}$ g/g
$Mdnorm_{Pu}$	239.07461687 g/mol	$3.86 \cdot 10^{-6}$ g/mol
$Rd_{238/239}$	$28.741 \cdot 10^{-6}$ mol/mol	$135 \cdot 10^{-9}$ mol/mol
$Rd_{240/239}$	0.02241703 mol/mol	$2.55 \cdot 10^{-6}$ mol/mol
$Rd_{241/239}$	$154.52 \cdot 10^{-6}$ mol/mol	$1.01 \cdot 10^{-6}$ mol/mol
$Rd_{242/239}$	$75.718 \cdot 10^{-6}$ mol/mol	$390 \cdot 10^{-9}$ mol/mol
$fdnorm_{238}$	$28.104 \cdot 10^{-6}$	$132 \cdot 10^{-9}$
$fdnorm_{239}$	0.97782679	$2.65 \cdot 10^{-6}$
$fdnorm_{240}$	0.02191997	$2.44 \cdot 10^{-6}$
$fdnorm_{241}$	$151.096 \cdot 10^{-6}$	$986 \cdot 10^{-9}$
$fdnorm_{242}$	$74.039 \cdot 10^{-6}$	$381 \cdot 10^{-9}$
$wdnorm_{238}$	$27.983 \cdot 10^{-6}$	$132 \cdot 10^{-9}$
$wdnorm_{239}$	0.97773495	$2.66 \cdot 10^{-6}$
$wdnorm_{240}$	0.02200975	$2.45 \cdot 10^{-6}$
$wdnorm_{241}$	$152.349 \cdot 10^{-6}$	$994 \cdot 10^{-9}$
$wdnorm_{242}$	$74.963 \cdot 10^{-6}$	$386 \cdot 10^{-9}$
M_{Pu}	239.07479084 g/mol	$4.49 \cdot 10^{-6}$ g/mol
f_{238}	$30.143 \cdot 10^{-6}$	$142 \cdot 10^{-9}$
f_{239}	0.97773050	$2.88 \cdot 10^{-6}$
f_{240}	0.02193284	$2.44 \cdot 10^{-6}$
f_{241}	$232.50 \cdot 10^{-6}$	$1.52 \cdot 10^{-6}$
f_{242}	$74.014 \cdot 10^{-6}$	$381 \cdot 10^{-9}$
ΣR_{Pu}	1.02277673	$3.01 \cdot 10^{-6}$
λ_{238}	$7.90001 \cdot 10^{-3}$ a^{-1}	$2.70 \cdot 10^{-6}$ a^{-1}
λ_{239}	$28.7613 \cdot 10^{-6}$ a^{-1}	$13.1 \cdot 10^{-9}$ a^{-1}
λ_{240}	$105.647 \cdot 10^{-6}$ a^{-1}	$113 \cdot 10^{-9}$ a^{-1}
λ_{241}	0.0483872 a^{-1}	$40.5 \cdot 10^{-6}$ a^{-1}
λ_{242}	$1.8583 \cdot 10^{-6}$ a^{-1}	$14.9 \cdot 10^{-9}$ a^{-1}
λ_{244}	$8.6643 \cdot 10^{-9}$ a^{-1}	$97.5 \cdot 10^{-12}$ a^{-1}
ΣRd_{Pu}	1.02267601	$2.77 \cdot 10^{-6}$
$c_{y.IRMM046bdec}$	$465.0352 \cdot 10^{-9}$ mol/g	$90.0 \cdot 10^{-12}$ mol/g
$R_{239/242Pu.IRMM046bdec}$	$2.21167 \cdot 10^{-3}$ mol/mol	$8.00 \cdot 10^{-6}$ mol/mol
$Rd_{239/242}$	13206.9 mol/mol	68.0 mol/mol

Quantity	Value	Standard Uncertainty
ε_1	$773 \cdot 10^{-12}$	$600 \cdot 10^{-12}$
ε_2	$-539 \cdot 10^{-12}$	$589 \cdot 10^{-12}$
ε_3	$-451 \cdot 10^{-12}$	$547 \cdot 10^{-12}$
ε_4	$611 \cdot 10^{-12}$	$645 \cdot 10^{-12}$
ε_5	$-394 \cdot 10^{-12}$	$528 \cdot 10^{-12}$
c_{Pu1}	$3.067792 \cdot 10^{-6}$ mol/g	$912 \cdot 10^{-12}$ mol/g
c_{Pu2}	$3.069134 \cdot 10^{-6}$ mol/g	$899 \cdot 10^{-12}$ mol/g
c_{Pu3}	$3.069044 \cdot 10^{-6}$ mol/g	$853 \cdot 10^{-12}$ mol/g
c_{Pu4}	$3.067958 \cdot 10^{-6}$ mol/g	$964 \cdot 10^{-12}$ mol/g
c_{Pu5}	$3.068985 \cdot 10^{-6}$ mol/g	$831 \cdot 10^{-12}$ mol/g
γ_{Pu1}	$733.431 \cdot 10^{-6}$ g/g	$218 \cdot 10^{-9}$ g/g
γ_{Pu2}	$733.752 \cdot 10^{-6}$ g/g	$215 \cdot 10^{-9}$ g/g
γ_{Pu3}	$733.731 \cdot 10^{-6}$ g/g	$204 \cdot 10^{-9}$ g/g
γ_{Pu4}	$733.471 \cdot 10^{-6}$ g/g	$231 \cdot 10^{-9}$ g/g
γ_{Pu5}	$733.717 \cdot 10^{-6}$ g/g	$199 \cdot 10^{-9}$ g/g
Δ_γ	1.001358	$297 \cdot 10^{-6}$
$diff_{Pu}$	-0.1356 %	0.0296 %

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
c_{239Pu1}	$2.9998 \cdot 10^{-6}$ mol/g	$1.8 \cdot 10^{-9}$ mol/g	2.00	manual
c_{239Pu2}	$3.0011 \cdot 10^{-6}$ mol/g	$1.8 \cdot 10^{-9}$ mol/g	2.00	manual
c_{239Pu3}	$3.0010 \cdot 10^{-6}$ mol/g	$1.7 \cdot 10^{-9}$ mol/g	2.00	manual
c_{239Pu4}	$2.9999 \cdot 10^{-6}$ mol/g	$1.9 \cdot 10^{-9}$ mol/g	2.00	manual
c_{239Pu5}	$3.0009 \cdot 10^{-6}$ mol/g	$1.6 \cdot 10^{-9}$ mol/g	2.00	manual
γ_{239Pu1}	$717.10 \cdot 10^{-6}$ g/g	$430 \cdot 10^{-9}$ g/g	2.00	manual
γ_{239Pu2}	$717.41 \cdot 10^{-6}$ g/g	$420 \cdot 10^{-9}$ g/g	2.00	manual
γ_{239Pu3}	$717.39 \cdot 10^{-6}$ g/g	$400 \cdot 10^{-9}$ g/g	2.00	manual
γ_{239Pu4}	$717.14 \cdot 10^{-6}$ g/g	$450 \cdot 10^{-9}$ g/g	2.00	manual
γ_{239Pu5}	$717.38 \cdot 10^{-6}$ g/g	$390 \cdot 10^{-9}$ g/g	2.00	manual

Annex 19: Uncertainty budget for the characterisation of plutonium (turret B) of IRMM-1027r by ID-TIMS

Characterisation IRMM-1027r single vials IDMS Pu239 with 046b spike turret B

Author: Rozle Jakopic

Isotope amount ratios from MP2 certificate (IRMM, 01/01/2007) decayed to the date of IDMS measurement (4 Dec 2015)

mass spectrometry data: test report 3372 (IDMS) MP2 (1 Jan 2007)

Spike IRMM-046b

Date of measurement (IDMS): 4 Dec 2015

mass metrology certificates: dispensing (E3870), E3869 (blend mixtures)

IRMM-1027r vials (analytical sequence): 610, 894, 1085, 756, 971

Model Equation:

$f_{c242Pu}(m_x,m_y,R_b)=c_{y.IRMM046bdec}*(Rd_{239/242})*m_y/m_x*(R_{239/242Pu.IRMM046bdec}-(1/R_b))/(1/R_b-Rd_{239/242})$;

$c_{239Pu1}=f_{c242Pu}(m_{x1},m_{y1},R_{b1})$;
$c_{239Pu2}=f_{c242Pu}(m_{x2},m_{y2},R_{b2})$;
$c_{239Pu3}=f_{c242Pu}(m_{x3},m_{y3},R_{b3})$;
$c_{239Pu4}=f_{c242Pu}(m_{x4},m_{y4},R_{b4})$;
$c_{239Pu5}=f_{c242Pu}(m_{x5},m_{y5},R_{b5})$;

{----------concentration calculations----------}

$c_{239Pu}=(c_{239Pu1}+c_{239Pu2}+c_{239Pu3}+c_{239Pu4}+c_{239Pu5})/5$;

$c_{Pu1}=c_{239Pu1}/fdnorm_{239}$;
$c_{Pu2}=c_{239Pu2}/fdnorm_{239}$;
$c_{Pu3}=c_{239Pu3}/fdnorm_{239}$;
$c_{Pu4}=c_{239Pu4}/fdnorm_{239}$;
$c_{Pu5}=c_{239Pu5}/fdnorm_{239}$;
$c_{Pu}=c_{239Pu}/fdnorm_{239}$;

$\gamma_{239Pu1}=c_{239Pu1}*M_{239Pu}$;
$\gamma_{239Pu2}=c_{239Pu2}*M_{239Pu}$;
$\gamma_{239Pu3}=c_{239Pu3}*M_{239Pu}$;
$\gamma_{239Pu4}=c_{239Pu4}*M_{239Pu}$;
$\gamma_{239Pu5}=c_{239Pu5}*M_{239Pu}$;
$\gamma_{239Pu}=c_{239Pu}*M_{239Pu}$;

$\gamma_{Pu1}=Mdnorm_{Pu}*c_{Pu1}$;
$\gamma_{Pu2}=Mdnorm_{Pu}*c_{Pu2}$;
$\gamma_{Pu3}=Mdnorm_{Pu}*c_{Pu3}$;
$\gamma_{Pu4}=Mdnorm_{Pu}*c_{Pu4}$;
$\gamma_{Pu5}=Mdnorm_{Pu}*c_{Pu5}$;
$\gamma_{Pu}=Mdnorm_{Pu}*c_{Pu}$;

{----------operator----------}

$\varepsilon_1 = c_{239Pu} - c_{239Pu1}$;

$\varepsilon_2 = c_{239Pu} - c_{239Pu2}$;

$\varepsilon_3 = c_{239Pu} - c_{239Pu3}$;

$\varepsilon_4 = c_{239Pu} - c_{239Pu4}$;

$\varepsilon_5 = c_{239Pu} - c_{239Pu5}$;

{----------amount fractions----------}

$f_{238} = R_{238/239}/\Sigma R_{Pu}$;

$f_{239} = 1/\Sigma R_{Pu}$;

$f_{240} = R_{240/239}/\Sigma R_{Pu}$;

$f_{241} = R_{241/239}/\Sigma R_{Pu}$;

$f_{242} = R_{242/239}/\Sigma R_{Pu}$;

$f_{244} = R_{244/239}/\Sigma R_{Pu}$;

$M_{Pu} = M_{238Pu} \cdot f_{238} + M_{239Pu} \cdot f_{239} + M_{240Pu} \cdot f_{240} + M_{241Pu} \cdot f_{241} + M_{242Pu} \cdot f_{242} + M_{244Pu} \cdot f_{244}$;

{----------sum of ratios)----------}

$\Sigma R_{Pu} = R_{238/239} + 1 + R_{240/239} + R_{241/239} + R_{242/239} + R_{244/239}$;

{----------decayed spike parameters----------}

$R_{239/242Pu.IRMM046bdec} = R_{239/242Pu.IRMM046b} * e^{(-\lambda_{239} \cdot \Delta t_{spike})}/(e^{(-\lambda_{242} \cdot \Delta t_{spike})})$;

$c_{y.IRMM046bdec} = c_{y.IRMM046b} * e^{(-\lambda_{242} \cdot \Delta t_{spike})}$;

{----------decayed isotopic ratios in the sample to 4 Dec 2015 (IDMS analysis)----------}

$Rd_{238/239} = R_{238/239} \cdot (e^{(-\lambda_{238} \cdot \Delta t_{norm})}/e^{(-\lambda_{239} \cdot \Delta t_{norm})})$;

$Rd_{240/239} = R_{240/239} \cdot (e^{(-\lambda_{240} \cdot \Delta t_{norm})}/e^{(-\lambda_{239} \cdot \Delta t_{norm})})$;

$Rd_{241/239} = R_{241/239} \cdot (e^{(-\lambda_{241} \cdot \Delta t_{norm})}/e^{(-\lambda_{239} \cdot \Delta t_{norm})})$;

$Rd_{242/239} = R_{242/239} \cdot (e^{(-\lambda_{242} \cdot \Delta t_{norm})}/e^{(-\lambda_{239} \cdot \Delta t_{norm})})$;

$Rd_{244/239} = R_{244/239} \cdot (e^{(-\lambda_{244} \cdot \Delta t_{norm})}/e^{(-\lambda_{239} \cdot \Delta t_{norm})})$;

$Rd_{239/242}=1/Rd_{242/239}$;

{----------normalised decayed amount fractions----------}

$fdnorm_{238} = Rd_{238/239}/\Sigma Rd_{Pu}$;

$fdnorm_{239} = 1/\Sigma Rd_{Pu}$;

$fdnorm_{240} = Rd_{240/239}/\Sigma Rd_{Pu}$;

$fdnorm_{241} = Rd_{241/239}/\Sigma Rd_{Pu}$;

$fdnorm_{242} = Rd_{242/239}/\Sigma Rd_{Pu}$;

$fdnorm_{244} = Rd_{244/239}/\Sigma Rd_{Pu}$;

{----------normalised decayed mass fractions----------}

$wdnorm_{238} = fdnorm_{238} \cdot M_{238Pu}/Mdnorm_{Pu}$;

$wdnorm_{239} = fdnorm_{239} \cdot M_{239Pu}/Mdnorm_{Pu}$;

$wdnorm_{240} = fdnorm_{240} \cdot M_{240Pu}/Mdnorm_{Pu}$;

$wdnorm_{241} = fdnorm_{241} \cdot M_{241Pu}/Mdnorm_{Pu}$;

$wdnorm_{242} = fdnorm_{242} \cdot M_{242Pu} / Mdnorm_{Pu}$;

$wdnorm_{244} = fdnorm_{244} \cdot M_{244Pu} / Mdnorm_{Pu}$;

$Mdnorm_{Pu} = M_{238Pu} \cdot fdnorm_{238} + M_{239Pu} \cdot fdnorm_{239} + M_{240Pu} \cdot fdnorm_{240} + M_{241Pu} \cdot fdnorm_{241} + M_{242Pu} \cdot fdnorm_{242} + M_{244Pu} \cdot fdnorm_{244}$;

$\Sigma Rd_{Pu} = Rd_{238/239} + 1 + Rd_{240/239} + Rd_{241/239} + Rd_{242/239} + Rd_{244/239}$;

$ln_2 = ln(2)$;

$\lambda_{238} = ln_2 / \tau_{238}$;

$\lambda_{239} = ln_2 / \tau_{239}$;

$\lambda_{240} = ln_2 / \tau_{240}$;

$\lambda_{241} = ln_2 / \tau_{241}$;

$\lambda_{242} = ln_2 / \tau_{242}$;

$\lambda_{244} = ln_2 / \tau_{244}$;

{----------metrological versus IDMS values 4 Dec 2015----------}

$\Delta_y = c_{239Pumixture} / c_{239Pu}$;

$diff_{Pu} = (c_{239Pu} - c_{239Pumixture}) / c_{239Pumixture} * 100$;

List of Quantities:

Quantity	Unit	Definition
c_{Pu}	mol/g	amount content of Pu in IRMM-1027r
c_{239Pu}	mol/g	amount content of ^{239}Pu in IRMM-1027r
γ_{239Pu}	g/g	mass content of ^{239}Pu in IRMM-1027r
γ_{Pu}	g/g	mass content of Pu in IRMM-1027r
Δt_{norm}	a	time difference MP2 (01/01/2007) and measurement Pu IDMS, 4 Dec 2015
$Mdnorm_{Pu}$	g/mol	molar mass of decayed Pu
$Rd_{238/239}$	mol/mol	isotope amount ratio n_{238}/n_{239} after decay, IRMM-1027r, 4 Dec 2015
$Rd_{240/239}$	mol/mol	isotope amount ratio n_{240}/n_{239} after decay, IRMM-1027r, 4 Dec 2015
$Rd_{241/239}$	mol/mol	isotope amount ratio n_{241}/n_{239} after decay, IRMM-1027r, 4 Dec 2015
$Rd_{242/239}$	mol/mol	isotope amount ratio n_{242}/n_{239} after decay, IRMM-1027r, 4 Dec 2015
$Rd_{244/239}$	mol/mol	isotope amount ratio n_{244}/n_{239} after decay, IRMM-1027r, 4 Dec 2015
$fdnorm_{238}$		normalised decayed mole fraction of ^{238}Pu , IRMM-1027r, 4 Dec 2015
$fdnorm_{239}$		normalised decayed mole fraction of ^{239}Pu , IRMM-1027r, 4 Dec 2015
$fdnorm_{240}$		normalised decayed mole fraction of ^{240}Pu, IRMM-1027r, 4 Dec 2015
$fdnorm_{241}$		normalised decayed mole fraction of ^{241}Pu, IRMM-1027r, 4 Dec 2015
$fdnorm_{242}$		normalised decayed mole fraction of ^{242}Pu, IRMM-1027r, 4 Dec 2015
$fdnorm_{244}$		normalised decayed mole fraction of ^{244}Pu, IRMM-1027r, 4 Dec 2015

Quantity	Unit	Definition
$wdnorm_{238}$		normalised decayed mass fraction of ^{238}Pu, IRMM-1027r, 4 Dec 2015
$wdnorm_{239}$		normalised decayed mass fraction of ^{239}Pu, IRMM-1027r, 4 Dec 2015
$wdnorm_{240}$		normalised decayed mass fraction of ^{240}Pu, IRMM-1027r, 4 Dec 2015
$wdnorm_{241}$		normalised decayed mass fraction of ^{241}Pu, IRMM-1027r, 4 Dec 2015
$wdnorm_{242}$		normalised decayed mass fraction of ^{242}Pu, IRMM-1027r, 4 Dec 2015
$wdnorm_{244}$		normalised decayed mass fraction of ^{244}Pu, IRMM-1027r, 4 Dec 2015
$R_{238/239}$	mol/mol	isotope amount ratio n_{238}/n_{239} of Pu in IRMM-1027r
$R_{240/239}$	mol/mol	isotope amount ratio n_{240}/n_{239} of Pu in MP2
$R_{241/239}$	mol/mol	isotope amount ratio n_{241}/n_{239} of Pu in MP2
$R_{242/239}$	mol/mol	isotope amount ratio n_{242}/n_{239} of Pu in MP2
$R_{244/239}$	mol/mol	isotope amount ratio n_{244}/n_{239} of Pu in MP2
$Rd_{239/242}$	mol/mol	isotope amount ratio n_{239}/n_{242} of Pu in MP2
f_{238}		mole fraction of ^{238}Pu
M_{Pu}	g/mol	molar mass of Pu
f_{239}		mole fraction of ^{239}Pu
f_{240}		mole fraction of ^{240}Pu
f_{241}		mole fraction of ^{241}Pu
f_{242}		mole fraction of ^{242}Pu
f_{244}		mole fraction of ^{244}Pu
e		
ln_2		
ΣR_{Pu}		
τ_{238}	a	half life ^{238}Pu
τ_{239}	a	half life ^{239}Pu
τ_{240}	a	half life ^{240}Pu
τ_{241}	a	half life ^{241}Pu
τ_{242}	a	half life ^{242}Pu
τ_{244}	a	half life ^{244}Pu
λ_{238}	a^{-1}	decay constant ^{238}Pu
λ_{239}	a^{-1}	decay constant ^{239}Pu
λ_{240}	a^{-1}	decay constant ^{240}Pu
λ_{241}	a^{-1}	decay constant ^{241}Pu
λ_{242}	a^{-1}	decay constant ^{242}Pu
λ_{244}	a^{-1}	decay constant ^{244}Pu

Quantity	Unit	Definition
M_{238Pu}	g/mol	atomic mass for ^{238}Pu
M_{239Pu}	g/mol	atomic mass for ^{239}Pu
M_{240Pu}	g/mol	atomic mass for ^{240}Pu
M_{241Pu}	g/mol	atomic mass for ^{241}Pu
M_{242Pu}	g/mol	atomic mass for ^{242}Pu
M_{244Pu}	g/mol	atomic mass for ^{244}Pu
ΣRd_{Pu}		
$c_{y.IRMM046bdec}$	mol/g	decayed amount content of ^{242}Pu in IRMM-046b
$c_{y.IRMM046b}$	mol/g	amount content of ^{242}Pu in IRMM-046b
$R_{239/242Pu.IRMM046bdec}$	mol/mol	decayed isotope amount ratio n_{239}/n_{242} of Pu in IRMM-046b
$R_{239/242Pu.IRMM046b}$		isotope amount ratio n_{239}/n_{242} of Pu in IRMM-046b
Δt_{spike}	a	time difference certificate 046b (1 June 2010) and measurement date IRMM-1027r (4 Dec 2015)
c_{239Pu1}	mol/g	amount content of ^{239}Pu in vial 610
c_{239Pu2}	mol/g	amount content of ^{239}Pu in vial 894
c_{239Pu3}	mol/g	amount content of ^{239}Pu in vial 1085
c_{239Pu4}	mol/g	amount content of ^{239}Pu in vial 756
c_{239Pu5}	mol/g	amount content of ^{239}Pu in vial 971
$c_{239Pumixture}$	mol/g	metrological (gravimetrical) amount content ^{239}Pu in IRMM-1027r
R_{b1}	mol/mol	measured $^{242}Pu/^{239}Pu$ ratio in blend 1, vial 610
R_{b2}	mol/mol	measured $^{242}Pu/^{239}Pu$ ratio in blend 2, vial 894
R_{b3}	mol/mol	measured $^{242}Pu/^{239}Pu$ ratio in blend 4, vial 1085
R_{b4}	mol/mol	measured $^{242}Pu/^{239}Pu$ ratio in blend 4, vial 756
R_{b5}	mol/mol	measured $^{242}Pu/^{239}Pu$ ratio in blend 5, vial 971
m_{x1}	g	mass of sample 1027r in vial 610
m_{x2}	g	mass of sample 1027r in vial 894
m_{x3}	g	mass of sample 1027r in vial 1085
m_{x4}	g	mass of sample 1027r in vial 756
m_{x5}	g	mass of sample 1027r in vial 971
m_{y1}	g	mass of spike in blend 1, vial 610
m_{y2}	g	mass of spike in blend 2, vial 894
m_{y3}	g	mass of spike in blend 3, vial 1085
m_{y4}	g	mass of spike in blend 4, vial 756
m_{y5}	g	mass of spike in blend 5, vial 971
ε_1		
ε_2		
ε_3		
ε_4		

Quantity	Unit	Definition
ε_5		
c_{Pu1}	mol/g	Pu amount content in vial 610
c_{Pu2}	mol/g	Pu amount content in vial 894
c_{Pu3}	mol/g	Pu amount content in vial 1085
c_{Pu4}	mol/g	Pu amount content in vial 756
c_{Pu5}	mol/g	Pu amount content in vial 971
γ_{Pu1}	g/g	Pu mass content in vial 610
γ_{Pu2}	g/g	Pu mass content in vial 894
γ_{Pu3}	g/g	Pu mass content in vial 1085
γ_{Pu4}	g/g	Pu mass content in vial 756
γ_{Pu5}	g/g	Pu mass content in vial 971
γ_{239Pu1}	g/g	^{239}Pu mass content in vial 610
γ_{239Pu2}	g/g	^{239}Pu mass content in vial 894
γ_{239Pu3}	g/g	^{239}Pu mass content in vial 1085
γ_{239Pu4}	g/g	^{239}Pu mass content in vial 756
γ_{239Pu5}	g/g	^{239}Pu mass content in vial 971
Δ_γ		
$diff_{Pu}$	%	relative difference (IDMS-metrological/metrological)

Δt_{norm}: Constant
Value: 8.922656 a

01/01/2007, 4/12/2015, delta t= 3259 days/365.25=8.922656

$R_{238/239}$: Type B normal distribution
Value: 0.00003083 mol/mol
Expanded Uncertainty: 0.00000029 mol/mol
Coverage Factor: 2

MP2 certificate

$R_{240/239}$: Type B normal distribution
Value: 0.0224324 mol/mol
Expanded Uncertainty: 0.0000051 mol/mol
Coverage Factor: 2

MP2 certificate

$R_{241/239}$: Type B normal distribution
Value: 0.0002378 mol/mol
Expanded Uncertainty: 0.0000031 mol/mol
Coverage Factor: 2

MP2 certificate

$R_{242/239}$: Type B normal distribution
Value: 0.00007570 mol/mol
Expanded Uncertainty: 0.00000078 mol/mol
Coverage Factor: 2

MP2 certificate

$R_{244/239}$:
Type B normal distribution
Value: 0 mol/mol
Expanded Uncertainty: 0 mol/mol
Coverage Factor: 1

MP2 certificate

e:
Constant
Value: 2.71828182845904523536

τ_{238}:
Type B normal distribution
Value: 87.74 a
Expanded Uncertainty: 0.03 a
Coverage Factor: 1

τ_{239}:
Type B normal distribution
Value: 24100 a
Expanded Uncertainty: 11 a
Coverage Factor: 1

τ_{240}:
Type B normal distribution
Value: 6561 a
Expanded Uncertainty: 7 a
Coverage Factor: 1

τ_{241}:
Type B normal distribution
Value: 14.325 a
Expanded Uncertainty: 0.024 a
Coverage Factor: 2

τ_{242}:
Type B normal distribution
Value: 373000 a
Expanded Uncertainty: 3000 a
Coverage Factor: 1

τ_{244}:
Type B normal distribution
Value: $8 \cdot 10^7$ a
Expanded Uncertainty: $0.09 \cdot 10^7$ a
Coverage Factor: 1

M_{238Pu}:
Type B normal distribution
Value: 238.0495599 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al, 2003

M_{239Pu}:
Type B normal distribution
Value: 239.0521634 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al, 2003

M_{240Pu}: Type B normal distribution
Value: 240.0538135 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al, 2003

M_{241Pu}: Type B normal distribution
Value: 241.0568515 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al, 2003

M_{242Pu}: Type B normal distribution
Value: 242.0587426 g/mol
Expanded Uncertainty: 0.0000040 g/mol
Coverage Factor: 2

G. Audi et al, 2003

M_{244Pu}: Type B normal distribution
Value: 244.064204 g/mol
Expanded Uncertainty: 0.000010 g/mol
Coverage Factor: 2

G. Audi et al, 2003

$c_{y,IRMM046b}$: Type B normal distribution
Value: $4.6504 \cdot 10^{-7}$ mol/g
Expanded Uncertainty: $0.0018 \cdot 10^{-7}$ mol/g
Coverage Factor: 2

IRMM-046b certificate

$R_{239/242Pu,IRMM046b}$: Type B normal distribution
Value: 0.002212
Expanded Uncertainty: 0.000016
Coverage Factor: 2

IRMM-046b certificate

Δt_{spike}: Constant
Value: 5.508556 a

01/06/2010, 04/12/2015, delta t= 2012days/365.25=5.508556

$c_{239Pumixture}$: Import
Filename: ..\..\mother solution verification\IRMM-1027r Plutonium gravimetric mixture_1Dec_2015.smu
Symbol: $c_{Pumixture239}$

gravimetric mixture, decayed to 1 Dec 2015

R_{b1}: Type B normal distribution
Value: 0.183782 mol/mol
Expanded Uncertainty: 0.000059 mol/mol
Coverage Factor: 2

InternalTest Report 3372

R_{b2}: Type B normal distribution
Value: 0.184989 mol/mol
Expanded Uncertainty: 0.000069 mol/mol
Coverage Factor: 2

InternalTest Report 3372

R_{b3}: Type B normal distribution
Value: 0.185426 mol/mol
Expanded Uncertainty: 0.000087 mol/mol
Coverage Factor: 2

InternalTest Report 3372

R_{b4}: Type B normal distribution
Value: 0.185473 mol/mol
Expanded Uncertainty: 0.000068 mol/mol
Coverage Factor: 2

InternalTest Report 3372

R_{b5}: Type B normal distribution
Value: 0.181696 mol/mol
Expanded Uncertainty: 0.000062 mol/mol
Coverage Factor: 2

InternalTest Report 3372

m_{x1}: Type B normal distribution
Value: 2.5640 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

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m_{x2}: Type B normal distribution
Value: 2.5203 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

E3869

m_{x3}: Type B normal distribution
Value: 2.5146 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

E3869

m_{x4}: Type B normal distribution
Value: 2.5184 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

E3869

m_{x5}: Type B normal distribution
Value: 2.5684 g
Expanded Uncertainty: 0.0006 g
Coverage Factor: 2

E3869

m_{y1}:
Type B normal distribution
Value: 3.04049 g
Expanded Uncertainty: 0.00012 g
Coverage Factor: 2

E3869

m_{y2}:
Type B normal distribution
Value: 3.00875 g
Expanded Uncertainty: 0.00011 g
Coverage Factor: 2

E3869

m_{y3}:
Type B normal distribution
Value: 3.00936 g
Expanded Uncertainty: 0.00011 g
Coverage Factor: 2

E3869

m_{y4}:
Type B normal distribution
Value: 3.01388 g
Expanded Uncertainty: 0.00010 g
Coverage Factor: 2

E3869

m_{y5}:
Type B normal distribution
Value: 3.01073 g
Expanded Uncertainty: 0.00011 g
Coverage Factor: 2

E3869

Input Correlation:

The abundance set for Pu is assumed as uncorrelated.

Interim Results:

Quantity	Value	Standard Uncertainty
c_{Pu}	$3.068819 \cdot 10^{-6}$ mol/g	$669 \cdot 10^{-12}$ mol/g
c_{239Pu}	$3.000774 \cdot 10^{-6}$ mol/g	$654 \cdot 10^{-12}$ mol/g
γ_{239Pu}	$717.341 \cdot 10^{-6}$ g/g	$156 \cdot 10^{-9}$ g/g
γ_{Pu}	$733.677 \cdot 10^{-6}$ g/g	$160 \cdot 10^{-9}$ g/g
$Mdnorm_{Pu}$	239.07461674 g/mol	$3.86 \cdot 10^{-6}$ g/mol
$Rd_{238/239}$	$28.739 \cdot 10^{-6}$ mol/mol	$135 \cdot 10^{-9}$ mol/mol
$Rd_{240/239}$	0.02241702 mol/mol	$2.55 \cdot 10^{-5}$ mol/mol
$Rd_{241/239}$	$154.46 \cdot 10^{-6}$ mol/mol	$1.01 \cdot 10^{-5}$ mol/mol
$Rd_{242/239}$	$75.718 \cdot 10^{-6}$ mol/mol	$390 \cdot 10^{-9}$ mol/mol
$fdnorm_{238}$	$28.102 \cdot 10^{-6}$	$132 \cdot 10^{-9}$
$fdnorm_{239}$	0.97782686	$2.65 \cdot 10^{-6}$
$fdnorm_{240}$	0.02191996	$2.44 \cdot 10^{-6}$
$fdnorm_{241}$	$151.036 \cdot 10^{-6}$	$986 \cdot 10^{-9}$
$fdnorm_{242}$	$74.039 \cdot 10^{-6}$	$381 \cdot 10^{-9}$
$wdnorm_{238}$	$27.981 \cdot 10^{-6}$	$132 \cdot 10^{-9}$
$wdnorm_{239}$	0.97773503	$2.66 \cdot 10^{-6}$
$wdnorm_{240}$	0.02200974	$2.45 \cdot 10^{-6}$
$wdnorm_{241}$	$152.289 \cdot 10^{-6}$	$994 \cdot 10^{-9}$
$wdnorm_{242}$	$74.963 \cdot 10^{-6}$	$386 \cdot 10^{-9}$
$Rd_{239/242}$	13206.9 mol/mol	68.0 mol/mol
f_{238}	$30.143 \cdot 10^{-6}$	$142 \cdot 10^{-9}$
M_{Pu}	239.07479084 g/mol	$4.49 \cdot 10^{-6}$ g/mol
f_{239}	0.97773050	$2.88 \cdot 10^{-6}$
f_{240}	0.02193284	$2.44 \cdot 10^{-6}$
f_{241}	$232.50 \cdot 10^{-6}$	$1.52 \cdot 10^{-6}$
f_{242}	$74.014 \cdot 10^{-6}$	$381 \cdot 10^{-9}$
ΣR_{Pu}	1.02277673	$3.01 \cdot 10^{-6}$
λ_{238}	$7.90001 \cdot 10^{-3}$ a^{-1}	$2.70 \cdot 10^{-6}$ a^{-1}
λ_{239}	$28.7613 \cdot 10^{-6}$ a^{-1}	$13.1 \cdot 10^{-9}$ a^{-1}
λ_{240}	$105.647 \cdot 10^{-6}$ a^{-1}	$113 \cdot 10^{-9}$ a^{-1}
λ_{241}	0.0483872 a^{-1}	$40.5 \cdot 10^{-6}$ a^{-1}
λ_{242}	$1.8583 \cdot 10^{-5}$ a^{-1}	$14.9 \cdot 10^{-9}$ a^{-1}
λ_{244}	$8.6643 \cdot 10^{-9}$ a^{-1}	$97.5 \cdot 10^{-12}$ a^{-1}
ΣRd_{Pu}	1.02267593	$2.77 \cdot 10^{-6}$
$c_{y.IRMM046bdec}$	$465.0352 \cdot 10^{-9}$ mol/g	$90.0 \cdot 10^{-12}$ mol/g
$R_{239/242Pu.IRMM046bdec}$	$2.21167 \cdot 10^{-3}$ mol/mol	$8.00 \cdot 10^{-5}$ mol/mol

Quantity	Value	Standard Uncertainty
ε_1	$155 \cdot 10^{-12}$	$553 \cdot 10^{-12}$
ε_2	$-281 \cdot 10^{-12}$	$597 \cdot 10^{-12}$
ε_3	$-598 \cdot 10^{-12}$	$683 \cdot 10^{-12}$
ε_4	$191 \cdot 10^{-12}$	$592 \cdot 10^{-12}$
ε_5	$533 \cdot 10^{-12}$	$568 \cdot 10^{-12}$
c_{Pu1}	$3.068661 \cdot 10^{-6}$ mol/g	$853 \cdot 10^{-12}$ mol/g
c_{Pu2}	$3.069106 \cdot 10^{-6}$ mol/g	$904 \cdot 10^{-12}$ mol/g
c_{Pu3}	$3.06943 \cdot 10^{-6}$ mol/g	$1.00 \cdot 10^{-9}$ mol/g
c_{Pu4}	$3.068623 \cdot 10^{-6}$ mol/g	$898 \cdot 10^{-12}$ mol/g
c_{Pu5}	$3.068274 \cdot 10^{-6}$ mol/g	$871 \cdot 10^{-12}$ mol/g
γ_{Pu1}	$733.639 \cdot 10^{-6}$ g/g	$204 \cdot 10^{-9}$ g/g
γ_{Pu2}	$733.745 \cdot 10^{-6}$ g/g	$216 \cdot 10^{-9}$ g/g
γ_{Pu3}	$733.823 \cdot 10^{-6}$ g/g	$240 \cdot 10^{-9}$ g/g
γ_{Pu4}	$733.630 \cdot 10^{-6}$ g/g	$215 \cdot 10^{-9}$ g/g
γ_{Pu5}	$733.546 \cdot 10^{-6}$ g/g	$208 \cdot 10^{-9}$ g/g
Δ_γ	1.001281	$298 \cdot 10^{-6}$
$diff_{Pu}$	-0.1280 %	0.0297 %

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
c_{239Pu1}	$3.0006 \cdot 10^{-6}$ mol/g	$1.7 \cdot 10^{-9}$ mol/g	2.00	manual
c_{239Pu2}	$3.0011 \cdot 10^{-6}$ mol/g	$1.8 \cdot 10^{-9}$ mol/g	2.00	manual
c_{239Pu3}	$3.0014 \cdot 10^{-6}$ mol/g	$2.0 \cdot 10^{-9}$ mol/g	2.00	manual
c_{239Pu4}	$3.0006 \cdot 10^{-6}$ mol/g	$1.8 \cdot 10^{-9}$ mol/g	2.00	manual
c_{239Pu5}	$3.0002 \cdot 10^{-6}$ mol/g	$1.7 \cdot 10^{-9}$ mol/g	2.00	manual
γ_{239Pu1}	$717.30 \cdot 10^{-6}$ g/g	$400 \cdot 10^{-9}$ g/g	2.00	manual
γ_{239Pu2}	$717.41 \cdot 10^{-6}$ g/g	$420 \cdot 10^{-9}$ g/g	2.00	manual
γ_{239Pu3}	$717.48 \cdot 10^{-6}$ g/g	$470 \cdot 10^{-9}$ g/g	2.00	manual
γ_{239Pu4}	$717.30 \cdot 10^{-6}$ g/g	$420 \cdot 10^{-9}$ g/g	2.00	manual
γ_{239Pu5}	$717.21 \cdot 10^{-6}$ g/g	$410 \cdot 10^{-9}$ g/g	2.00	manual

Annex 20: Results of the confirmation measurements (10 units, 3 replicates) of ^{235}U and ^{238}U amount contents in the selected vials of IRMM-1027r

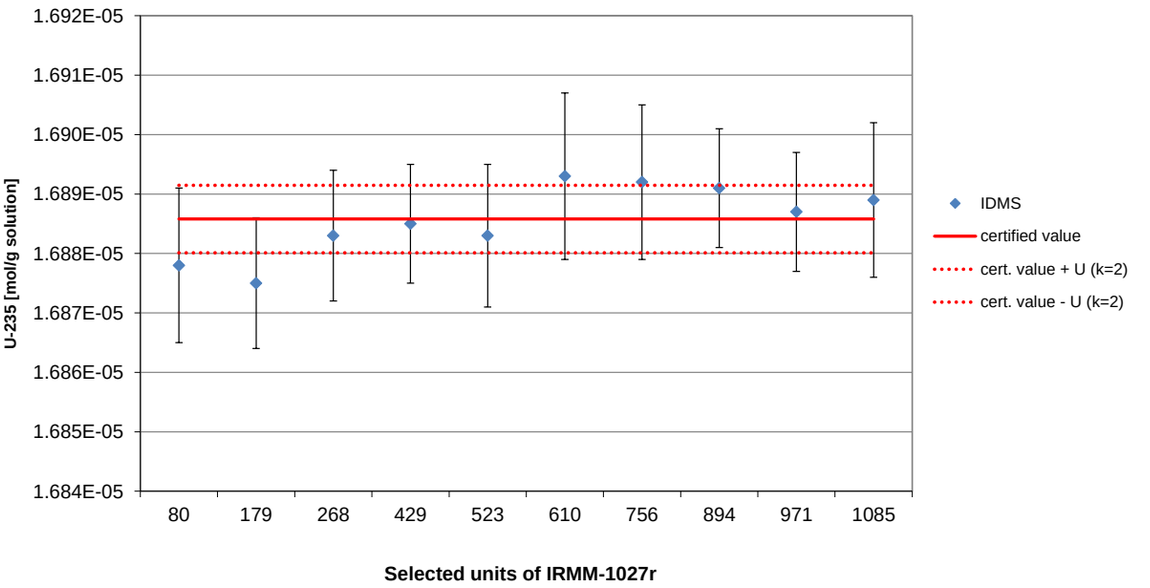

Fig 16. The certified amount content of ^{235}U in the selected vials of IRMM-1027r prepared by gravimetric mixing compared with the measured values by IDMS (with expanded uncertainties, coverage factor k = 2).

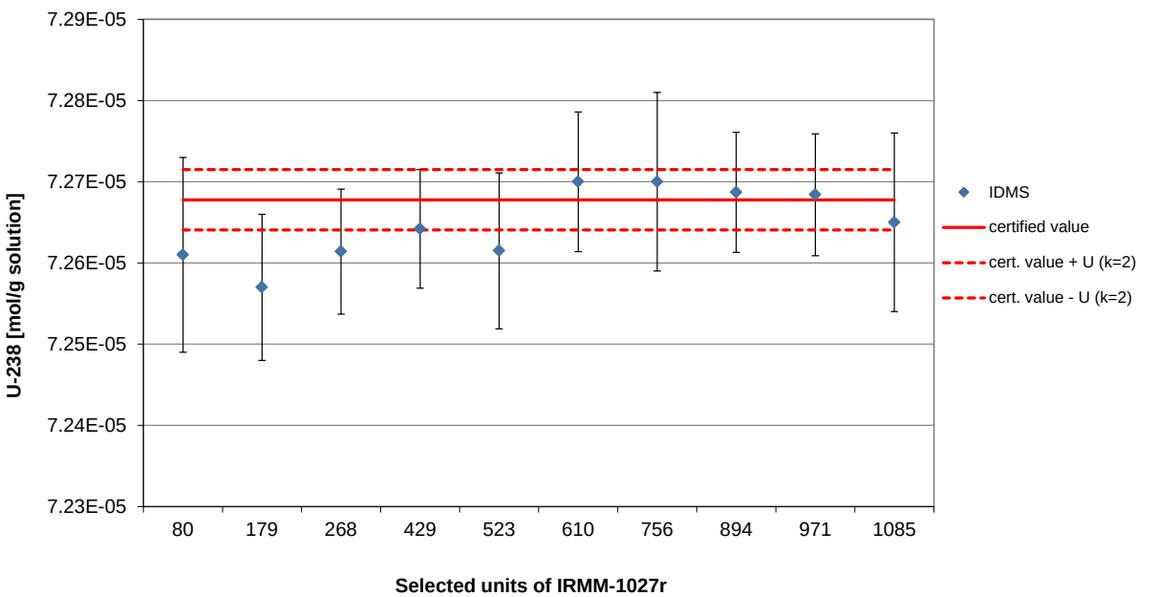

Fig 17. The certified amount content of ^{238}U in the selected vials of IRMM-1027r prepared by gravimetric mixing compared with the measured values by IDMS (with expanded uncertainties, coverage factor k = 2).

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